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A MONOGRAPH

OF THE

FOSSIL REPTILIA

OF THE

LIASSIC FORMATIONS.

(pl. 1 - 3)

BY

Richard
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PART FIRST.

SCELIDOSAURUS HARRISONII.

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MONOGRAPHS

ON THE

BRITISH FOSSIL

REPTILIA

FROM

THE OOLITIC FORMATIONS.

BY

RICHARD OWEN, F.R.S., D.C.L.,

FOREIGN ASSOCIATE OF THE INSTITUTE OF FRANCE, ETC. ETC.

PART FIRST,

CONTAINING

SCELIDOSAURUS HARRISONII AND PLIOSAURUS GRANDIS.

LONDON:

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A MONOGRAPH

OF A

FOSSIL DINOSAUR

(*SCELIDOSAURUS HARRISONII*, OWEN)

OF THE

LOWER LIAS.

In the year 1858 a few fragmentary fossils of limb-bones were submitted to my inspection by James Harrison, Esq., of Charmouth, Dorsetshire, obtained from the upper part of the "lower Lias," near that place. They included portions of a femur and of a tibia, in which the texture of the wall and the size of the cavity of the shaft showed them to have been parts of a Saurian of more terrestrial habits than any of those which had been previously discovered in Liassic deposits: traces, moreover, of the extent and direction of certain processes, although broken away in the fossils, were discernible, which led me to suspect they belonged to a reptile allied to *Iguanodon*. I therefore briefly notified the fact of a Liassic Dinosaur in my 'Palæontology,'* and indicated the animal by the generic name *Scelidosaurus*.† I propose, in the present monograph, to describe these very interesting fossils as they have successively come under my observation, and submit the proofs of the generic distinction and Dinosaurian affinities of the extinct animal.

* 8vo. ed., 1860, p. 258.

† Gr. σκελῖς, *limb*, σαυρος, *lizard*; from the indications of greater power in the hind legs than in most Saurians.

Femur. Tab. I.

I may premise that the femur of the *Iguanodon* is characterised by the deep and narrow fissure dividing a compressed external trochanter from the head of the bone, and by a process from the middle of the shaft, on the inner side, opposite to the part where the "third trochanter" projects in some of the large herbivorous mammals (*Perissodactyla*). Both these characters are repeated in the specimen of the uncompressed shaft of the femur represented in Tab. I; but the shaft, viewed sideways, as in fig. 3, shows a more decided sigmoid flexure than in the Iguanodon, and the fissure between the great trochanter (*e*) and the proximal end of the bone (*c*) is relatively deeper. The exterior surface of the shaft is smooth, and in the present fossil glistens, and is, as it were, bronzed by a thin coating of pyritic salt. The proximal end of the bone (*c*) divided by the cleft from the great trochanter (*e*) is subcompressed from side to side below the swelling out of the head, and is extended from before backwards; the head itself, or articular end of the bone, has been broken or abraded away, showing a fine cancellous structure at that part (fig. 3, *c*). The antero-posterior diameter of this part is 6 inches; the transverse diameter, opposite the base of the outer trochanter, is 3 inches 8 lines.

The fore part of the shaft (fig. 2) shows at its upper half a flattened, oblong, rather rough surface (*f*) for muscular implantation. Below, and on the outer side of this surface, is a rough, roundish, slightly prominent tuberosity (*s*), continued at its inner side into a ridge, which descends with a slight curve outwards on the fore part of the middle of the shaft of the femur, where it terminates in a point at *v*. These risings indicate the force of the large muscles acting upon the limb, and by their insertions raising and drawing forward the femur. The elongated base of the inner process (fig. 3, *t*) becomes slightly narrower as it descends; its full extent is not recognisable, by reason of the wall of the shaft being there broken away, exposing the medullary cavity (*m*). Behind the base of the process is a large, oblong, rough ridge, indicating the extension of the surface of attachment, behind and beyond the process itself, for a powerful muscle depressing and drawing back the femur. I do not find this character so well marked in the femur of the Iguanodon. The homologous roughness is present, without the process, in the femur of the Megalosaur. From the great trochanter (*e*) a narrow, rough surface, not projecting as a ridge, extends nearly straight down the outer and back part of the shaft (fig. 1 *o*). Exterior to this surface is an oval foramen (*a*), most probably for the passage of the blood-vessels and nerve to the medullary cavity.

The transverse section of the middle of the shaft is nearly circular; the thickness of the compact wall of the medullary cavity is here about one sixth of the transverse diameter of the bone. I have not seen a bone of any other Dinosaur indicative of more vigorous action of the hind limbs than the present femoral shaft.

The foregoing interesting and instructive fossil was accompanied by the shaft of a tibia of corresponding size, crushed and broken at both ends; it measured 18 inches in length and 2 inches 8 lines in diameter at its middle, the circumference of the shaft there being 10 inches.

These proportions indicate a hind leg, longer and more slender, relatively to the trunk, than in the *Megalosaur, Iguanodon*, or other Dinosaur with which such comparison may be made. The bone being fractured across the middle of the shaft, shows a large medullary cavity; the compact, bony wall does not exceed 3 lines in thickness, the cavity itself being 1 inch 3 lines in diameter.

At the proximal end the antero-posterior expansion and its ridges have been broken away. The bone gradually contracts, as it descends, to a subtriedral shaft, with a triangular transverse section, two of the angles being rounded off, and the third remaining, which was opposite the fibula. The distal expansion has been, in like manner, broken away; but its commencement shows the rise of an anterior ridge in addition to the fibular one. I did not think it necessary to figure this fossil, as I shortly after received from Mr. Harrison and Mr. Henry Morris, F.R.C.S., of Charmouth, the subjects of the two following plates.

Parts of the Femur, Tibia, and Fibula forming the Knee-joint. Tab. II.

In the specimen figured from three views (figs. 1, 2 and 3) in this plate, the lower half of the right femur and the upper half of the right tibia and fibula are cemented by the matrix in the natural relative position in which they enter into the formation of the knee-joint, when bent. This remarkable specimen indicates the tranquil state of the sea-bed or bottom after it had received the dead carcass of the Dinosaur. No agitation or other external violence has displaced the bones of the leg after the solution of the ligaments which tied them together in the living animal; when the depth to which they had sunk, and the consistency of the mud or clay bed, tended to retain them in their natural position. The portion of femur preserved indicates a slight backward bend of the shaft, which at the fractured part—probably a little below the middle of the bone—presents an almost circular transverse section. The circumference here is 10 inches; the compact wall of the bone is 6 lines thick; the medullary cavity 2 inches in diameter. A little below the fractured end, and 8 inches above

the lower end, the shaft shows the termination of the inner process. From this point the femur expands gradually, and chiefly in the transverse direction. Posteriorly it becomes impressed by the popliteal cavity, which deepens and widens to the upper and back part of the inner condyle; which, by its production towards the outer condyle, contracts the lower end of the popliteal cavity transversely. On the outer side of the distal expansion of the femur, the external wall is in part broken away; but a shallow and narrow longitudinal impression is indicated, terminating below in a rather shallow notch, which marks out the inner and hinder part of the outer condyle from the outer part of the same condyle. This notch corresponds with that between the tibia and fibula, and defines the portions of the outer condyle assigned to those bones respectively. The inner condyle is rather flattened on the inner side (*a*). The tibia is much expanded at the proximal end, chiefly by an extension of the bone forward (fig. 1); it is slightly convex on the inner or tibial side (*e*); a longitudinal prominence extends from the fibular side of the expansion, near the fore part, answering to the ectocnemial process in the bird's tibia; the main expansion forms the procnemial process (figs. 1 and 2, *p*) which has subsided to the ordinary level of the shaft about six inches down the bone. The back part of the proximal end of the tibia (fig. 3) presents two almost hemispheric protuberances (fig. 3, *c*, *d*), side by side; they might be mistaken in a detached bone for the backwardly projecting condyles of a femur, but are less deeply severed. The outer tuberosity (*d*) articulates with a slight depression in the contiguous part of the fibula (*f*). The fore part of the proximal portion of the tibia is, transversely, concave, exterior to the pro- and ecto-cnemial processes. The fractured part of the shaft, eleven inches below the knee-joint, presents a full, oval section, with the same proportion of compact bony wall to medullary cavity as in the femur; the white spar filling the cavity (*m*) contrasts strongly with the jet-black colour of the petrified bone (*t'*). The transverse diameter of this part of the shaft is 2 inches 3 lines; the fore and aft diameter is 2 inches 6 lines.

The fibula expands chiefly in the fore and aft direction at its upper end (fig. 2, *f*), where it measures 5 inches across. Six inches lower down this diameter has contracted to one of 1 inch 8 lines; eleven inches lower it measures 1 inch 3 lines, the transverse diameter being 9 lines. Seven inches from the proximal end the fibula presents at its outer and back part a thick, longitudinal, rough ridge, for the attachment of a muscle. It continues in contact with, and gets rather behind, the tibia as it descends.

Ungual Phalanx. Tab. II, figs. 4, 5, 6.

The ungual phalanx transmitted with the foregoing leg-bones, from the collection of Henry Norris, Esq., F.R.C.S., is somewhat intermediate in its proportions between that of the hind foot of the *Megalosaurus* and that of the hind foot of the *Iguanodon;* it is less compressed than the former, less depressed and flattened than in the latter. On one side of the base, near the articular surface, it is impressed by a shallow, vertical canal (fig. 6, *g*), extending from the upper to the lower part of the bone. A median, low and broad, vertical prominence extends from the upper half of the articular facet (fig. 5, *b*), giving a sub-crescentic figure to the cavity of the joint; the lower border is straight to near the apex, which is slightly bent down (fig. 4). There are no indications of lateral grooves and foramina for blood-vessels.

Bones of a young Scelidosaur. Tab. III.

Subsequently to the exposure and acquisition of the foregoing fossils an intelligent quarry-man discovered, in the same member of the lower Lias, a collection of small bones, of a delicate, friable texture, of which those comprised in Tab. III were brought to Mr. Harrison, by whom they were kindly transmitted to me for description. The collection included the centrum or body of a vertebra (figs. 1—4), a left femur (figs. 5, 6), a considerable portion of a tibia (fig. 7), and fibula (figs. 8 and 9), a tarsal bone (fig. 15), a metatarsal (figs. 10 and 11), and a proximal phalanx (figs. 12—14). The long bones were much crushed, especially the femur. This bone, therefore, appears to be thicker than it really was, being almost flattened. The articular ends have been in a fibrous, unossified state, so that they appear flatter or less prominent than they were in the recent bone. The external trochanter (*e*) seems entire, and has not risen higher in relation to the head of the bone than is shown in fig. 5. The internal process (*t*) is similarly well preserved, repeating the character of the herbivorous Dinosauria which is exemplified in the Iguanodon. The outer condyle of the femur is longitudinally grooved for the fibula. The medullary or unossified cavity of the shaft of the bone has been more considerable, in relation to the compact shaft, than in the large femora previously described.

From the foregoing characters it may be concluded that the present femur has belonged to a Dinosaur, allied to the Iguanodon, and to a very young individual, and it most probably formed part of a very young or fœtal Scelidosaur.

Fig. 7, Tab. III, is a crushed tibia, with the upper end much produced forward and bilobed behind, as in that of the Scelidosaur, the lower end is wanting.

It bears the same proportion to the femur as does the tibia in the specimen figured in Tab. II.

The bone, with the shaft crushed flat, and with a sub-bilobed end (figs. 8 and 9), having the opposite extremity broken away, more resembles a fibula than it does a metatarsal bone.

The bone (figs. 10 and 11) presents the characters of a metatarsal at both its articular extremities, and might well belong, by its general proportions, to the same limb with the femur (fig. 5) and tibia (fig. 7) of Tab. III. Fig. 12 gives a side view, fig. 13 a back view, and fig. 14 a front view, of a proximal phalanx of one of the toes of a foot of corresponding dimensions.

A tarsal bone (Tab. III, fig. 15) presents a peculiar form; one of the larger surfaces (*a*) is impressed with a shallow cavity; it is separated from the opposite surface, for two thirds of its extent, by a smooth, convex, apparently articular, surface, broader at one end of the bone than at the other. The other third of the marginal surface (*b*) presents a triangular, rather flattened, facet. The opposite surface to *a* is also impressed by a cavity, bounded by a sharper margin, which at one end is notched, so that two slight angular projections here appear, as at *b*, fig. 15.

The vertebral centrum presents one terminal surface flat, the other slightly convex; it belongs to the dorsal or lumbar series, all the processes having been developed from the neural arch, which has separated from the sutural surfaces shown in fig. 2. The sides of the centrum (fig. 1) are smooth, concave lengthwise, convex vertically, converging towards the lower border, but in a less degree than in *Iguanodon;* that border is consequently less narrow. The neural canal sinks at the middle into the substance of the centrum (fig. 2). All the characters of this part agree with the Dinosaurian nature of the young reptile which is demonstrated by the femur (figs. 5 and 6).

From the texture, fragility, and evidences of incomplete ossification of the bones represented in Tab. III, I infer them to have belonged to a very young individual, and their occurrence in a marine deposit suggests many reflections.

To whatever extent the Saurian organization has been modified for terrestrial life, that has been, in no instance, such as to suggest an inability to swim. On the contrary, the disproportionate shortness of the fore limbs, even in the Iguanodon, leads to the suspicion that they might be short in reference to diminishing the obstacles to propelling the body through water by actions of the strong and vertically extended tail; and that, as in the living land lizard of the Gallopagos Islands, called *Amblyrhynchus*, the fore limbs might be applied close to the trunk in the Iguanodon, when it occasionally sought the water of the neighbouring estuary or sea. One would suppose that the newly born or newly hatched young of a Dinosaur might be safer on shore than at sea, or at least in waters which, like

those of the Liassic ocean, seem to have swarmed with carnivorous Enaliosaurs. If the Dinosauria were ovo-viviparous, and produced but few young at a birth, the remains from the lower Lias figured in Tab. III might be those of a fœtus borne by a gravid Scelidosaur to sea during an occasional excursion, and which by some casualty had there perished, and become imbedded, with her progeny, in the muddy bottom of the old Liassic ocean. I have not, however, been able to obtain precise evidence of the proximity of the small bones above described with any of the larger ones attributed to the *Scelidosaurus*, and bones of more than one small individual might have been expected to occur in juxtaposition if they had perished before birth. The analogy of the crocodile, moreover, would lead us to expect that the newly excluded or newly born Scelidosaur would be of smaller size than the individual indicated by the bones in Tab. III.

The Skull. Tabs. IV, V, VI.

The foregoing indications of a Dinosaur in the lower Lias excited speculation as to whether it had been herbivorous, like the Iguanodon of the newer Mezozoic beds, or carnivorous, like the Megalosaur, which has been traced from Wealden down to the "great Oolite." The structure of the femur pointed the former way, but the proof which the dentition only could give was wanting.

The persevering encouragement afforded by Mr. Harrison to the workmen in the Lias quarries has, however, been rewarded by the acquisition of the fine specimen of a skull which forms the subject of Tabs. IV, V, and VI.

The teeth, in their close-set, thecodont implantation, relative size to the jaw, degree of expansion, and general shape of the crown, resemble those ascribed to the *Hylæosaurus* (p. 21, tab. viii, figs. 1—3, 'Monograph on Wealden Reptilia,' 1857); but the crown presents the median longitudinal prominence and marginal serrations which bring it closer to the Iguanodont pattern; and, in the degree in which they depart therefrom, they still more closely resemble the teeth of the *Echinodon* from the Purbeck,* which may prove to be a small kind, or young, of a Dinosaur. They, however, present different proportions.

Referring, therefore, the skull in question to the Dinosaurian order, it supplies most acceptable information as to the cranial structure of that group, which no previous example from Oolitic and Wealden beds has been sufficiently perfect to impart.

Of *Iguanodon*, *Megalosaurus*, and *Hylæosaurus*, portions of lower jaw, and mere fragmentary bits of the upper jaw, palate, and basis cranii, are all that have hitherto come to light. But the present specimen is the entire skull, wanting only the fore end of the upper and lower jaws.

* 'Monograph on the Fossil Lacertian Reptiles of the Purbeck Limestones,' p. 35, 1858.

The cranium has been slightly crushed and distorted by oblique pressure, due to movements of the matrix after imbedding and petrifaction. The right halves of the mid-frontal and nasal are depressed a little below the level of the left halves of the same bones, and the right diverging branch of the parietal has been broken from the rest of the bone, near the median line, and dislocated by the same pressure from its union with the mastoid. The right ramus of the mandible, accompanying the movement of that side of the head, has been pushed so far below the left ramus as to have its inner side brought into view in the profile of the skull given in Tab. IV.

The occipital conforms to the Lacertian type in the proportions and direction of the par-occipital; this process is long, narrow, straight, directed outwards, compressed from before backward, and slightly expanded at the extremity, which is applied to the back part of the mastoid and tympanic at the junction of those bones. It has been slightly displaced, its end appearing on the left side at 4, Tab. IV, with matrix intervening between it and the tympanic (28). A part of the exoccipital which projects backward to contribute to the formation of the condyle, is exposed near the mass of matrix, including the atlas vertebra and nuchal dermal bones.

The cranial part of the skull, posterior to the orbits, is shorter in proportion than in the lizards, and resembles, in this respect, that of the crocodiles. The parietal is short, and bifurcate behind, as in lizards. The body of the bone, or part between the temporal fossæ, is subcompressed where it forms the smooth, concave, inner sides of those depressions, which do not meet above, but are separated by a narrow, flat tract; this might be converted into a ridge in older individuals. The fore part of the parietal slightly expands where it is overlapped by the frontals. Each hind branch of the parietal extends outward and a little backward; its pointed end is obliquely overlapped anteriorly by the inner branch of the mastoid, completing therewith the hind boundary of the temporal fossa. The crushed and dislocated state of the calvarium along its middle line does not permit the usual evidence of a foramen parietale to be detected, but the appearances are against such perforation being present. This foramen is not constant in modern lizards; the *Scelidosaurus* may agree with *Cyclodus* and *Tejus* in this respect. The parietal bone, as a whole, plainly accords with the lacertian, not with the crocodilian, type of that bone.

The mastoid (8) is a triradiate bone, forming the upper and hinder angle of the cranium, from which one ray passes inward to join the parietal (7), a second ray forward to join the post-frontal (Tab. V, 12), and a third ray downward to join the tympanic (28). A fracture of the body of the mastoid, by which the anterior branch is broken away on the left side (Tab. IV, 8), exposes a cancellous cavity, probably forming part of the organ of hearing.

The two halves of the mid-frontal have been separated along the medial line, and the right half depressed. The separation appears to have been at a suture, as is certainly the case with the nasal bones; the medial margin of three fourths of the left frontal show the jagged, sutural character. I conclude, therefore, that the mid-frontal was divided, as in the Ichthyosaurus, and as in *Varanus* and *Lacerta* proper; and that it was not a single bone, as in the Iguana and most *Lacertilia*, and as it is in the *Crocodilia*. Each half of the frontal in *Scelidosaurus* is a long, inequilateral triangle, the medial being the longest side, the posterior, which joins the parietal, the shortest; the antero-external border is irregularly and deeply notched, uniting with the post-frontal, super-orbital, pre-frontal, and nasal bones; it is excluded, as in *Lacerta* proper, by the large super-orbital bone (71) from the orbit. The outer surface of the frontal is sculptured by irregular lines and grooves, but less deeply than in *Crocodilus*.

The post-frontal (12) forms the back and part of the upper border of the orbit, uniting with the super-orbital, the frontal, and malar, and sending backward an angular process to join the mastoid, completing the upper bar or zygomatic arch of the temporal fossa. This arch had been broken away on the left side (Tab. IV), but is preserved on the right side (Tab. V, 8, 12).

The pre-frontal presents a horizontal and a vertical portion; the former and larger part is wedged between the frontal, superorbital, and nasal bones, the descending plate joins the lacrymal (73), and touches the upper angle of the maxillary (21). In the Crocodile the aspect of the whole outer plate of the pre-frontal is upward; in some Lacertians the major part looks outward.

The nasal bones (15, Tabs. V and VI) unite above and behind with the frontal (11) by a short border, obliquely and irregularly cut, to include the pointed anterior ends of the lateral halves of the frontal; the nasals expand as they advance, in union, first, with the pre-frontals, then with the maxillaries, where they slightly decrease in breadth. The mutilated fore part of the skull precludes the determination of the relations of the nasals with the pre-maxillary, and of the character of that bone. That of the outer plate of the nasals looks upward; the maxillary border is slightly bent down (15, fig. 2, Tab. V), and is overlapped by the maxillary (21, ib.)

The fractured fore part of the skull in the above-cited figure shows the superior thickness of the median and lateral borders of the nasals, the intervening part being, as it were, channeled below for the air-passage; this has not here been divided by any ossified vertical septum; the thickened palatal and alveolar parts of the maxillary, as they bend toward each other, present a convexity transversely to the nasal passage. This is closed below, as it seems, by the vomer (13).

Of the hind part of the bony palate the pterygoid was brought into view by removing the matrix between the diverging rami of the mandible. The body of

the bone is in the form of a subtriangular plate, of 1 inch 7 lines extent along its mesial border, which is slightly concave, receding from its fellow at the medial line, or base, as in the Iguana; the apex extends outward, and a little downward to abut against the fore and inner part of the ectopterygoid. From the hind border near the base a long and narrow process is sent off to abut against the tympanic. There is no trace of teeth on the pterygoid, as in the recent Iguanas; the higher type of Saurian dentition is retained in *Scelidosaurus*.

The hind and probably main part of the maxillary, here preserved, is chiefly remarkable for the horizontal ridge which nearly equally divides the outer or facial plate of the bone into an upper and lower facet; and this ridge is continued a little way below the orbit upon the malar bone. It corresponds with the more strongly marked ridge in *Ptychognathus* and *Oudenodon*. There is a lower and slighter longitudinal prominence of the maxillary along the outer alveolar plate. The maxillary reaches back beyond the middle of the orbit, from which it is separated, as in other Saurians, by the malar and lacrymal bones.

On both sides there is a small, unossified space between the maxillary and lacrymal; this corresponds with the larger vacuity in that part of the bones of the face in the Pterodactyle, which is reduced to the present proportions in some Teleosaurs, and becomes the functional nostril in the Ichthyosaur; but I believe that the true external nostrils of *Scelidosaurus* were included in the fore part of the skull which has been broken away, and were, as in the Teleosaur, distinct from the maxillo-lacrymal vacuities.

The orbits of *Scelidosaurus* are subcircular, almost vertical, looking outward. Were the super-orbital ossicle in *Crocodilia* enlarged and fixed by suture in the upper scoop of the orbit, it would give a less vertical outlook to the eye than it usually presents, especially in the skull of a crocodile from which that ossicle has been removed. But the composition of the rim of the orbit in *Scelidosaurus* is open to other homologies. The bone (71) may be compared with that wedged into the upper and back part of the orbit in some lizards, between the frontal and post-frontal, and by Cuvier regarded as a dismemberment of the latter element; only in *Scelidosaurus* it is extended forward to the pre-frontal, excluding the frontal from the orbit. In *Ichthyosaurus* the post-frontal has a like forward extension and junction with the pre-frontal, but it also passes backward to join the mastoid, leaving to the bone at the back of the orbit a simple post-orbital function. In *Scelidosaurus* the bone which joins the mastoid also sends down the post-orbital bar to join the malar; so that I find no nearer approach to the peculiar structure of the upper part of the orbit in *Scelidosaurus* than the Crocodile would give with a somewhat more fixed and developed superorbital bone.

The delicate lacrymal bone (73) appears to have been fractured on the left side

(Tab. IV); on the right side (Tab. V) it seems to be entire. The malar bone (26) begins anteriorly, in a pointed form, between the lacrymal and maxillary, increases in depth as it extends beneath the orbit, sends up a process which bifurcates to receive the point of the post-frontal in the cleft (Tab. V, 27), and extends backward and downward as a slightly convex and somewhat roughened plate, which articulates by its lower convex, but somewhat irregular, border with the squamosal (27). The posterior border of the malar presents a regular and well-defined, concave curve. The chief peculiarity of the bone is its unusual vertical extent posteriorly. This extent seems to be increased by the squamosal (Tabs. IV and V, 27), which articulates with the lower border of the produced part of the malar, and expands to be articulated with the outer part of the lower half of the tympanic (28), the upper angle rising above the terminal articular part of the malar. This deep and powerful arch of bone, answering to the zygoma in mammals, may have afforded attachment to large, masseteric muscles operating upon the lower jaw. Similar muscles may have been extended between the ridges of the upper and lower jaws. The tympanic is a long bone, compressed from before backward, almost vertical in position, with a slight forward bend, but firmly wedged between the mastoid and par-occipital above and between the squamosal and pterygoid below.

The back part of the tympanic is convex transversely at its inner half, concave at its outer half, where the margin is slightly produced to join the upper part of the squamosal; the inner part of the tympanic is more extended where it is overlapped or abutted on by the pterygoid (Tab. VI, fig. 2, 24). Below this expansion the tympanic becomes contracted and thickened, forming a kind of neck to the terminal condyle.

In the vertical position and length of the tympanic, *Scelidosaurus* resembles the *Lacertia;* in its fixity and extent of its connexions, it resembles the *Crocodilia.*

The lower jaw includes in each ramus an articular (29), a surangular (30), a coronoid (30′), an angular (31), a splenial (32) and a dentary (33) piece.

The articular (Tab. VI, fig. 2, 29) is situated in the inner side of the surangular, and is thickened and projects inward to form the cavity for the major part of the tympanic condyle, the outer border of which rests on the surangular. This element (30) convex externally, presents a longitudinal ridge near its upper part, which rises to join the posterior angle of the dentary element in forming a low coronoid process. The angular (31) does not extend beyond the surangular, but makes with it the angle of the lower jaw; it grows in vertical extent as it advances, is convex externally, unites with the dentary, and sends forward from its lower part a pointed process between the dentary and splenial elements. The splenial (32) makes a small appearance on the outer side of the ramus, between the angular and dentary, but is chiefly visible as a broad, smooth

plate (Tab. VI, fig. 2, 32), applied to the inner side of the dentary. The dentary (33) is a very powerful bone, with the outer surface divided into an upper and lower facet by a longitudinal ridge paralleling that of the upper jaw. The ridge (Tabs. IV and V, 33), commencing near the base of the coronoid process, descends, describing a slight curve to the middle of the outer surface of the dentary. Below the ridge the bone is convex, above it is concave; the lower facet has the kind and degree of roughness observable on the exposed surface of most of the cranial bones; the upper facet has a smoother surface, corresponding in that respect with the surface below the ridge of the maxillary.

The foregoing character of the lower jaw has, hitherto, been observed only in a fossil one, which has been referred to the Dinosaurian order; by Mantell,* originally to *Iguanodon*, and afterwards, when it had been shown to be more probably part of the *Hylæosaurus*,† to a genus which he called *Regnosaurus*.‡ In this portion of the ramus of the mandible (No. 422, Reptilian Fossils, British Museum), the outer surface of the dentary is divided into an upper and lower facet by a longitudinal ridge, which, commencing near the upper margin, probably at the base of a coronoid rising, descends as it advances to midway between the upper and lower border. It is, however, more obtuse than in *Scelidosaurus*, but the upper facet presents a like smoothness and vertical concavity.§ In size the specimens closely correspond, and also in the close arrangement of the series of teeth. But these were relatively smaller and more numerous in the Wealden fossil; for whereas in *Hylæosaurus* ten teeth, or their sockets, occupy an extent of 1 inch 8 lines of the alveolar border, the same extent includes only seven and a half teeth or sockets in *Scelidosaurus*. In this genus, moreover, the ramus of the mandible presents a curve convex downwards, to about the same degree as the opposite curve is presented by the corresponding part of the jaw of *Hylæosaurus*, in which this peculiar bend is noticed by me in a former monograph.‖ In the mandible of *Scelidosaurus* a ridge, corresponding, perhaps, to the lower ridge in *Hylæosaurus* is situated further back and higher up upon the surangular; and the facet, concave vertically between the lower ridge and the beginning of the upper ridge,¶ is peculiar to the mandibular fragment referred to the *Hylæosaurus*. Thus, with corresponding Dinosaurian character, imparting robust strength to the mandible, there are well-marked generic distinctions in the specimens here compared, both in the conformation of the jaws and teeth.**

The mandibular rami of *Scelidosaurus* describe a slight, but graceful, sigmoid

* 'Wonders of Geology,' 1838, vol. i, p. 393.

† "Report on British Fossil Reptiles," 'Trans. of Brit. Association,' 1841, p. 120.

‡ 'Philos. Trans.,' 1848.

§ See tab. viii, fig. 5, 'Monograph on Wealden Reptilia' (1856).

‖ Ib., p. 19. ¶ Ib., tab. viii, figs. 1 and 4. ** Ib., tab. viii, figs. 6—9.

curve from the angle forward, horizontally, at first concave, then convex, towards the median line, where they meet without blending at the part fractured. It is not probable that the symphysis would be much prolonged beyond this point. The degree of convergence of the contour lines of the whole skull, both median and lateral, with the decreasing size of the anterior teeth, makes it more probable that but a small proportion of the muzzle is wanting in the present specimen (Tabs. IV and V). The analogy of the Iguanodon might be unsafe ground for inferring as short a symphysis mandibulæ in *Scelidosaurus*, but it would accord with the other indications of such a proportion of the conjoined ends of the rami.

Dentition. Tabs. IV and V.

The specimen of *Scelidosaurus* here described has been buried and petrified with the mouth shut; there has been no dislocation of the under jaw, and the skull shows that the teeth of the upper jaw overlapped and concealed those of the lower. The crowns of both series were a little inclined inward, as shown at the fractured fore part (Tab. V, fig. 2, *a*, *b*); this, with the similar inclination of the alveolar plates, produces a feature which reminds one of that of toothless anility, or of the effect of sucking in the cheeks, in man.

The teeth are small, or of Lacertian proportions to the jaws; they are numerous and close-set, implanted in sockets forming an uninterrupted series along the alveolar border. The fang is simple, and longer than the crown, presenting a full ellipse in transverse section, and projecting a little beyond the socket. In the upper jaw the crown (Tab. V, fig. 3) begins by bulging outward, with a smooth convexity, subsiding as it gradually expands, and dividing to be continued along the middle and the margins, with intervening concavities, producing an undulated surface across the broadest part of the crown. The marginal convexities or ridges terminate each in a point at the broadest part of the crown; whence, the plate-shaped tooth having thinned off to an edge, this is divided on each side into five or six smaller points: these denticulate margins converge straight, at an angle rather less than a right one, to the apex of the tooth, which is formed by the pointed termination of the median convexity. The crown is coated by a polished enamel, of jet blackness in the fossil, smooth under the lens upon the convexities, finely punctate in the hollows of the expanded part of the crown. The whole tooth in the upper jaw is very slightly bent backward, with as slight an oblique twist, making the hinder angle overlap the front angle of the crown of the tooth behind.

The inner surface of four of the hind teeth of the right ramus of the jaw shows a crown with a larger proportion of the serrated part, and with the borders less equal, the anterior one showing as many as nine points, and the expanded coronal surface is uniformly and gently convex.

On the left side, in an extent of the alveolar border of the upper jaw measuring 4 inches, there are nineteen sockets, and only one tooth missing. On the right side, in an extent of $3\frac{1}{2}$ inches, there are sixteen sockets, and three teeth missing. The fractured part of the jaw yields evidence of the usual reptilian provision for successional teeth in reserve alveoli, containing tooth-germs, at the inner side of the base of the teeth in place (Tab. V, fig. 2, *c*). The teeth gradually increase in size from the hindmost to the fifth in advance, continue of about the same size to the tenth, and then gradually decrease in size to fractured fore part of the jaw.

Were the serrated borders of the terminal half of the crown to be worn down, the teeth of *Scelidosaurus* would be like those referred to *Hylæosaurus* in my Monograph of 1856.* There is no evidence, however, that any of them have been so worn down; in this respect they resemble more the teeth of *Echinodon*, the upper teeth in *Scelidosaurus* differing chiefly in the proportions of length to breadth of the crown. Whether the anterior teeth had the simple laniariform character at the fore part of the jaws in *Scelidosaurus*, as in *Echinodon*, remains to be proved. The finely and sharply serrated and pointed teeth of the *Scelidosaurus* glided upon each other, the upper on the outerside of the under, like the blade-shaped crowns of the carnassials of feline mammals; and yet the similarity of the teeth, in their number and uniformly small size, to those of the modern Iguanas suggests that they may have been put to like uses. The compressed, serrate crowns in those herbivorous lizards worked obliquely upon each other, in a similar scissor-blade way. In *Iguanodon* the dentition is obviously modified more decidedly for mastication of vegetable substances. In *Scelidosaurus* it is adapted for division of such substances, but it would be equally effective in piercing and cutting or tearing through animal textures.

If this Dinosaur occasionally went to sea in quest of food, it may be expected to present in the fore part of the jaws, wanting in the present specimen, laniariform teeth, as in *Echinodon*, for the prehension and retention of living prey. Should these prove to be absent, and the dental series to begin as it ends, it will incline the balance of probability to the phytophagous nature of the Liassic *Scelidosaurus*.

* 'Monograph on Wealden Reptilia,' p. 21, tab. viii, figs. 6—9.

TAB. I.

Scelidosaurus Harrisonii.

Shaft of femur, half nat. size.

Fig.

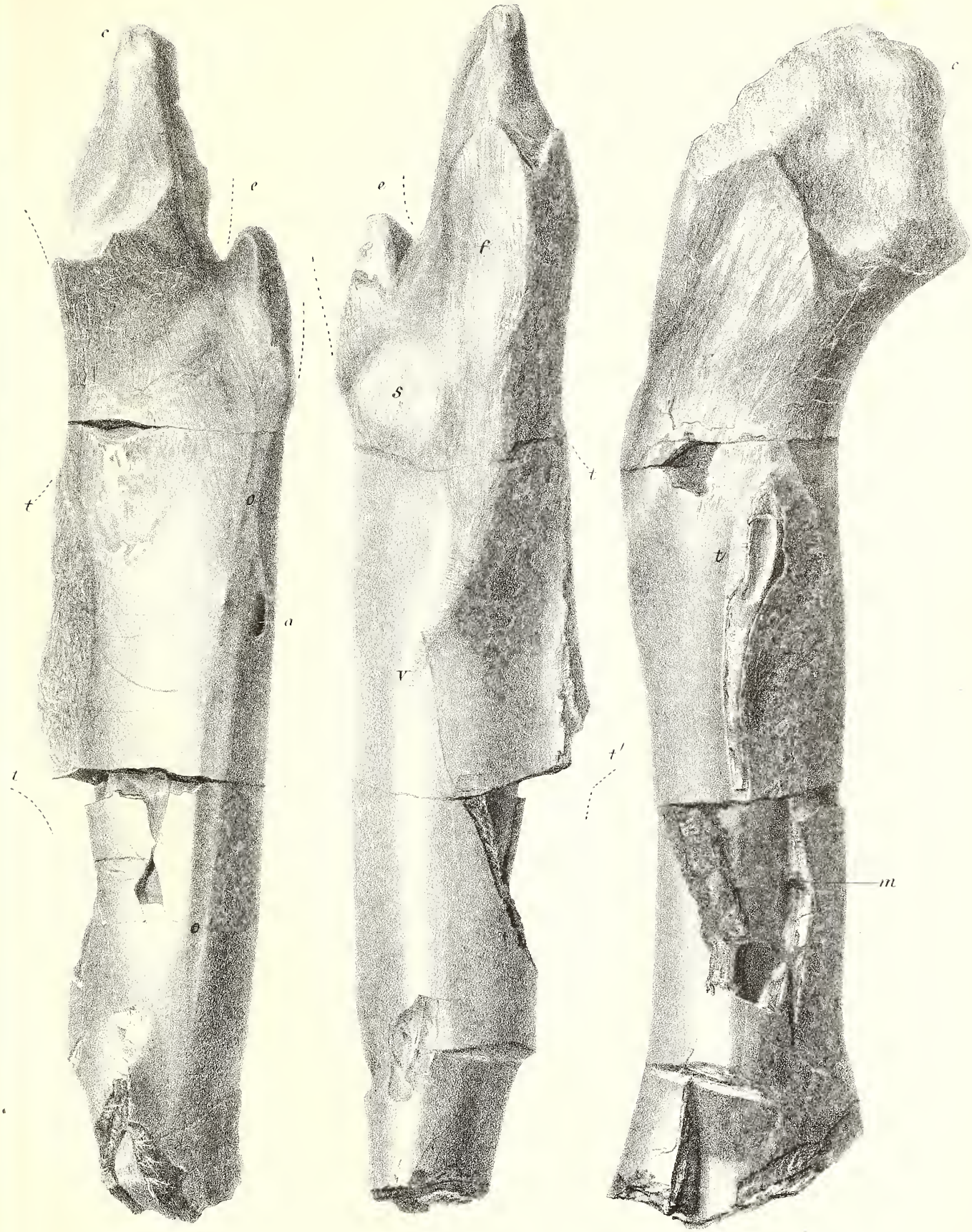
1. Front view.

2. Back view.

3. Inner side view.

From the upper part of the Lower Lias, Charmouth, Dorsetshire.
Mus. Norris.

1 2 3



Jos. Dinkel del et lith.

$\frac{1}{2}$

W. West, imp.

TAB. II.

Scelidosaurus Harrisonii.

Bones forming the knee-joint, one third nat. size.

Fig.

1. Inside view.

2. Outside view.

3. Back view.

From the upper part of the Lower Lias, Charmouth, Dorsetshire.
Mus. Harrison.

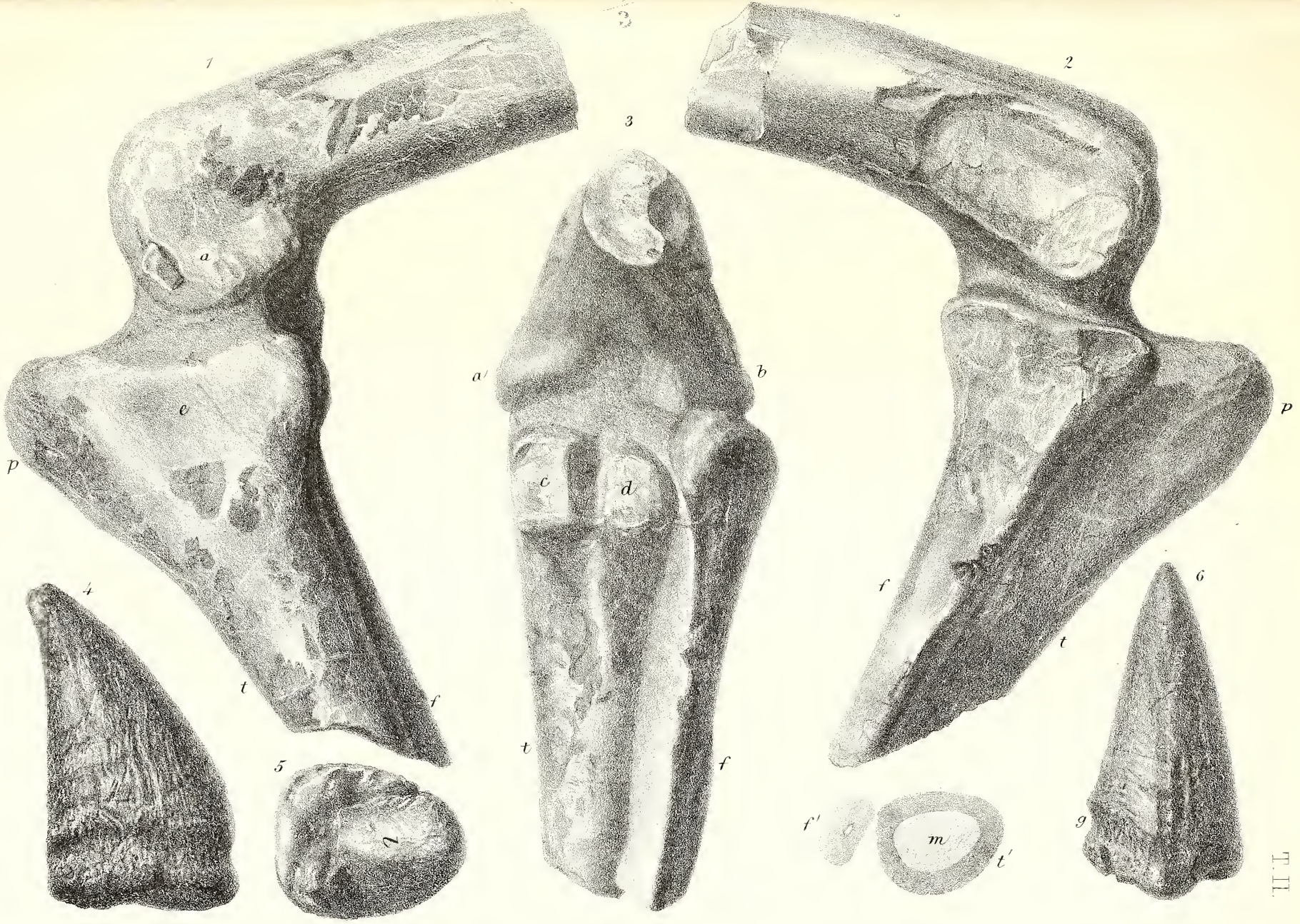
Ungual phalanx, or claw-bone, nat. size.

4. Side view.

5. Articular surface.

6. Upper view.

From the same formation and locality. Mus. Norris.



Jos. Dinkel del. et lith.

W.West, imp.

T. II.

TAB. III.

Scelidosaurus Harrisonii.

Bones of a very young individual, nat. size.

Fig.

1. Side view of centrum of dorsal vertebra.
2. Upper view of the same
3. End view of the same.
4. Under view of the same.
5. Front view of a crushed femur.
6. Back view of the same.
7. Tibia.
8, 9. Portion of fibula.
10, 11. Metatarsal bone.
12, 13, 14. Proximal phalanx.
15. Tarsal bone.

From the upper part of the Lower Lias, Charmouth, Dorsetshire.
Mus. Harrison.

F Robinson del. et lith

W.West imp.

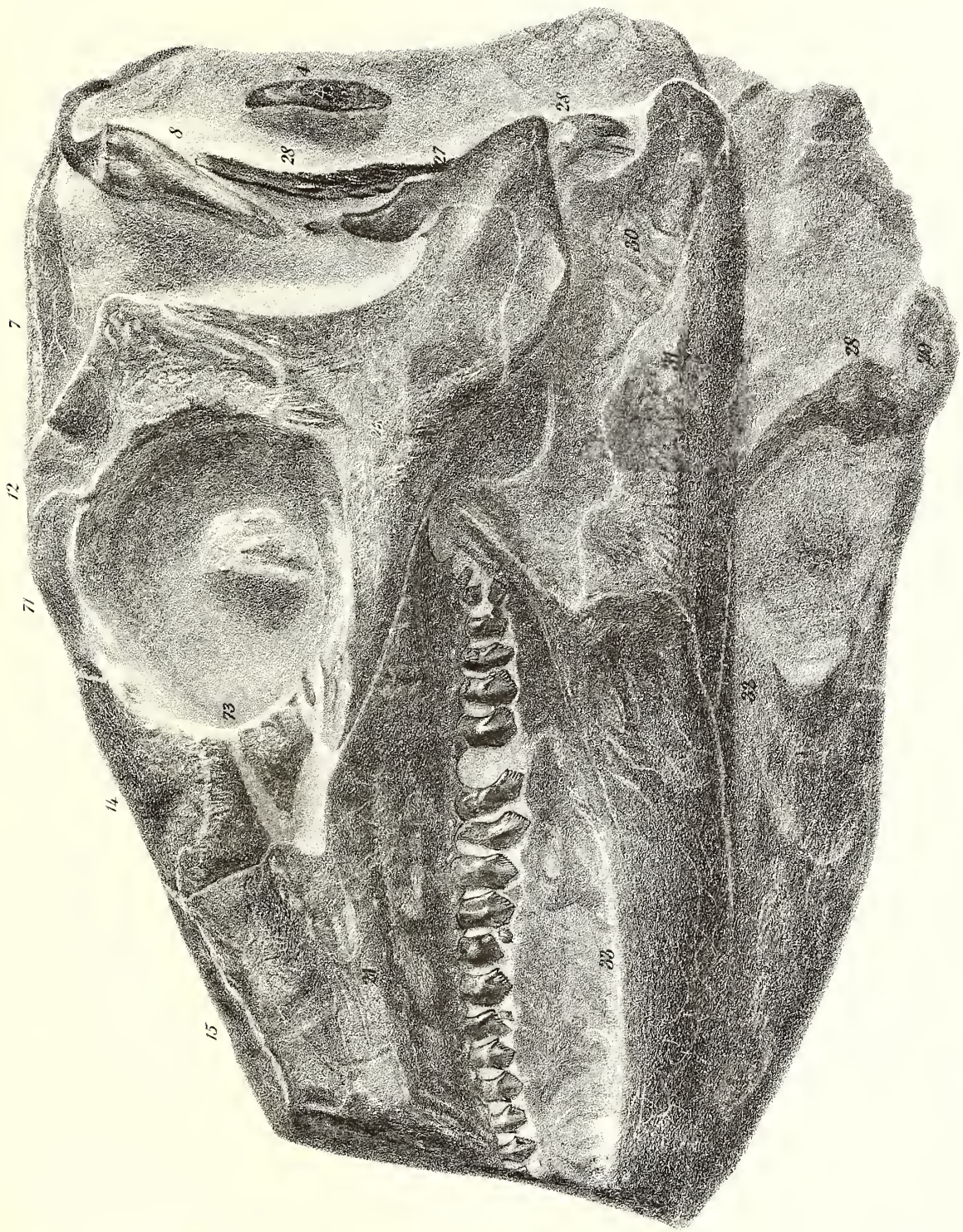
SCELIDOSAURUS.

TAB. IV.

Scelidosaurus Harrisonii.

Side view of the skull, nat. size.

From the upper part of the Lower Lias, Charmouth, Dorsetshire.
British Museum.



Jos. Dinkel del et lith.

W. West, imp.

SCELIDOSAURUS.

TAB. V.

Scelidosaurus Harrisonii.

Fig.

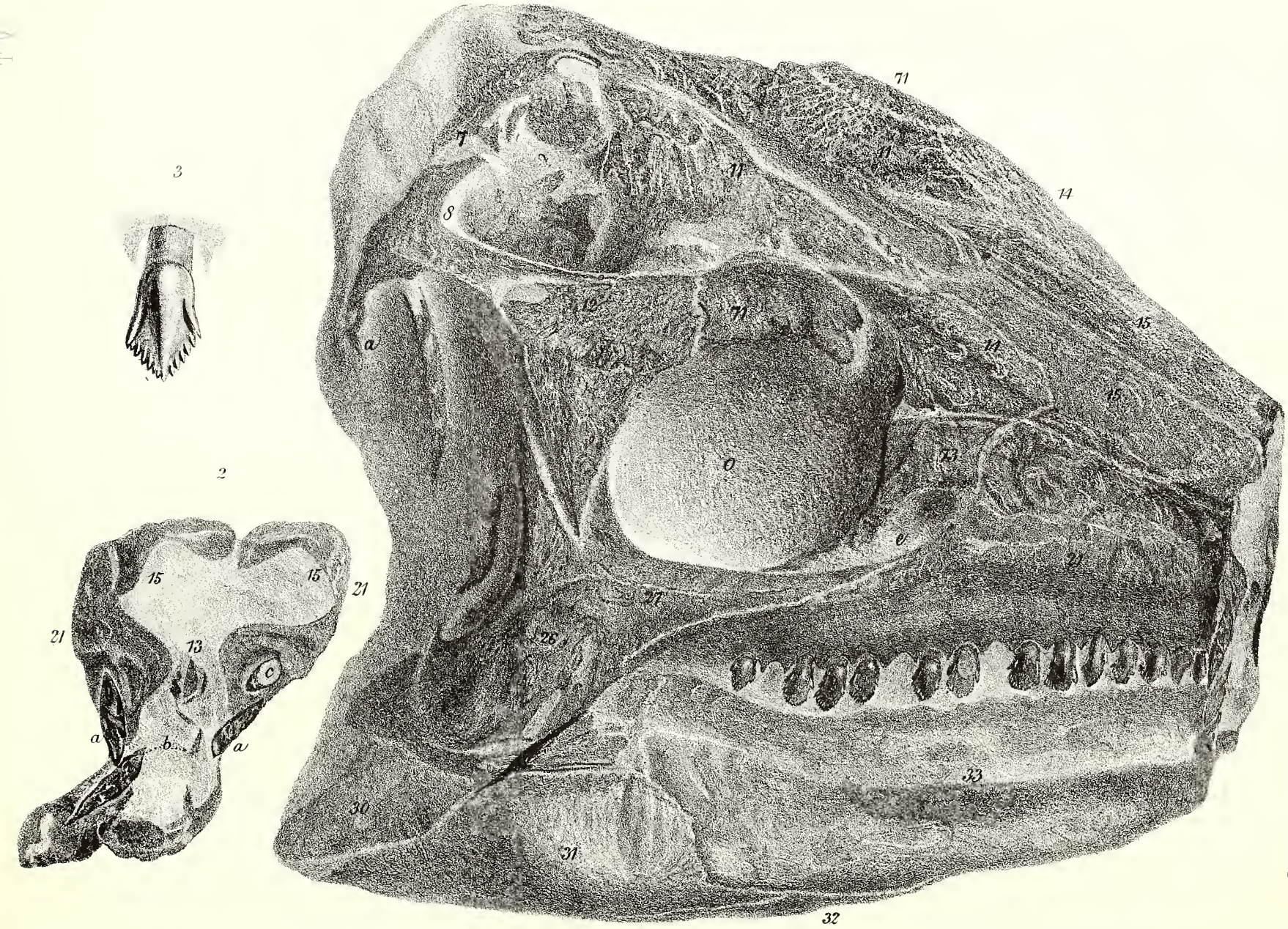
1. Side view of the skull, nat. size.

2. Fractured fore end of the same, nat. size.

3. Outer side of an upper tooth, magnified.

From the upper part of the Lower Lias, Charmouth, Dorsetshire.
British Museum.

Fig. 1.



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TAB. VI.

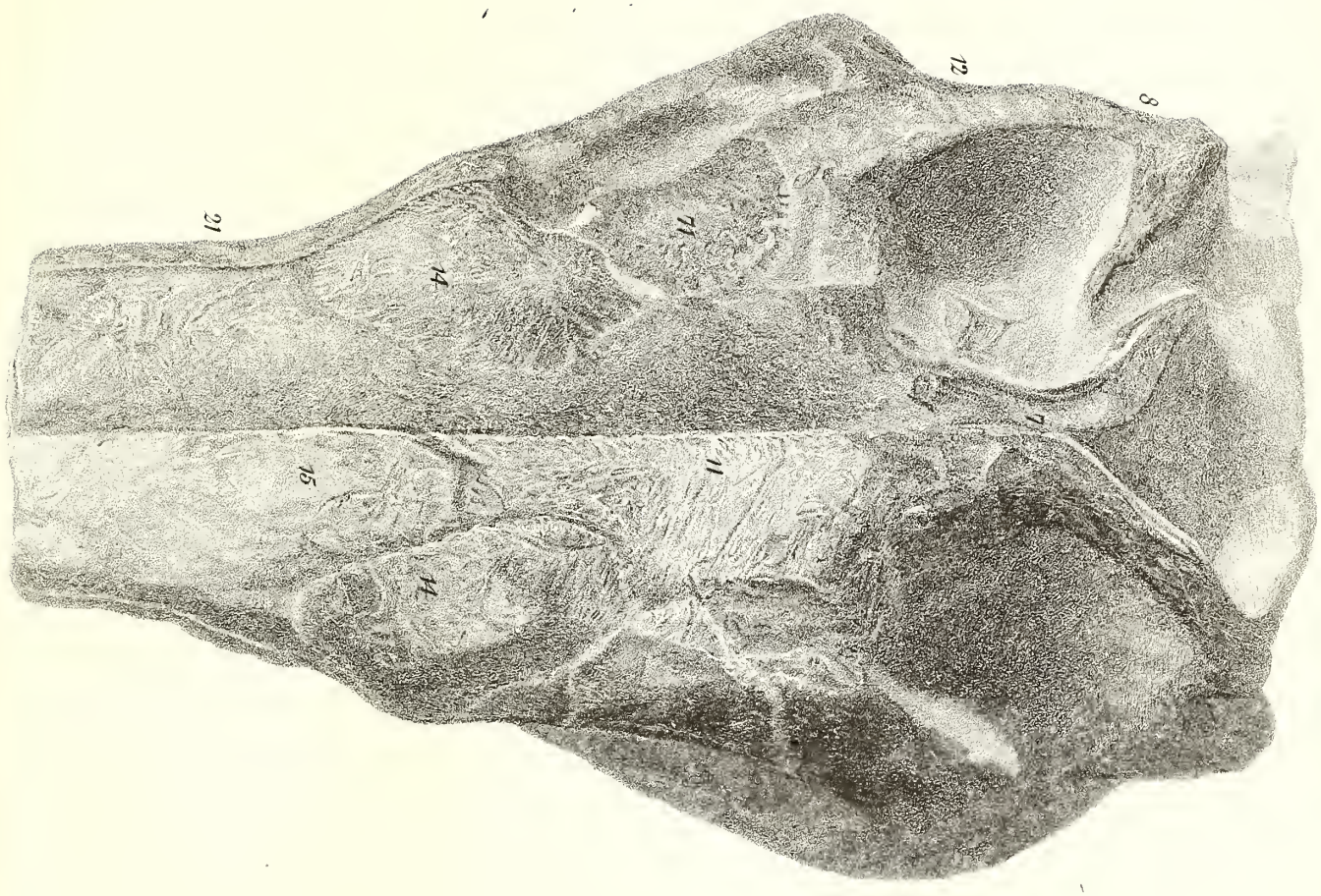
Scelidosaurus Harrisonii.

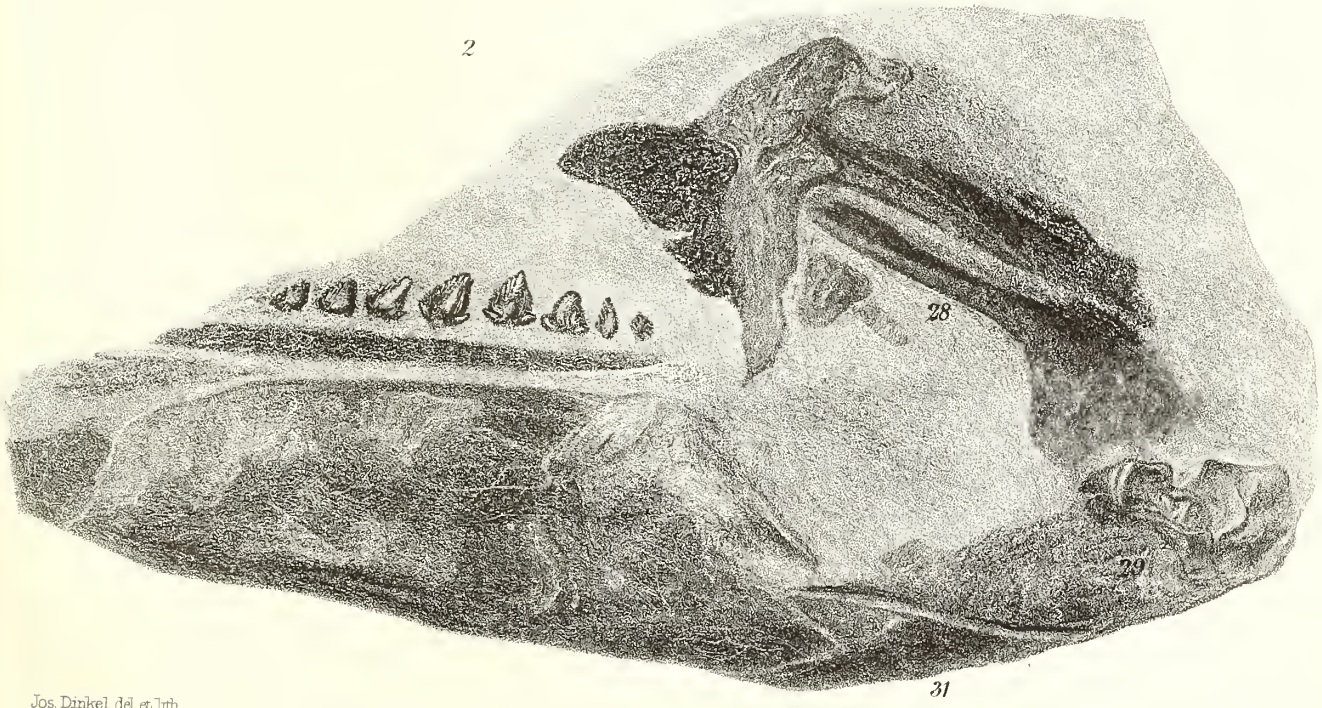
FIG.

1. Upper view of the skull, nat. size.

2. Inner view of right ramus of lower jaw, nat. size.

From the upper part of the Lower Lias, Charmouth, Dorsetshire.
British Museum.





Jos. Dinkel del. et lith.

W. West, imp.

THE

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MONOGRAPHS

ON THE

BRITISH FOSSIL

REPTILIA

FROM

THE OOLITIC FORMATIONS.

BY

RICHARD OWEN, F.R.S., D.C.L.,

FOREIGN ASSOCIATE OF THE INSTITUTE OF FRANCE, ETC., ETC.

Smithsonian Institution
National Museum

PART SECOND,

CONTAINING

SCELIDOSAURUS HARRISONII AND PLIOSAURUS GRANDIS.

LONDON:

PRINTED FOR THE PALÆONTOGRAPHICAL SOCIETY.

1862.

J. E. ADLARD, PRINTER, BARTHOLOMEW CLOSE.

A MONOGRAPH

OF

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OF THE

LIASSIC FORMATIONS.

BY

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ETC. ETC.

PART SECOND.

SCELIDOSAURUS HARRISONII.

Continued.

LONDON:
PRINTED FOR THE PALÆONTOGRAPHICAL SOCIETY.
1863.

PRINTED BY
J. E. ADLARD, BARTHOLOMEW CLOSE.

A MONOGRAPH

OF A

FOSSIL DINOSAUR

(*SCELIDOSAURUS HARRISONII*, OWEN)

OF THE

LOWER LIAS.

PART II.

THE continued attention paid by James Harrison, Esq., to the organic remains discovered during the quarrying operations on the face of the cliff of Lower Lias at Charmouth, Dorsetshire, with liberal encouragement to the workmen, has procured for the original discoverer of the first indication of the Scelidosaur the materials for the present account of an almost complete skeleton of that extinct reptile.

Following in the track opened out by the discovery of the skull described in the preceding Monograph,* about twelve successive blocks of Lias were secured, with more or less evident indications of included bones, all of which, together with the skull, have been purchased for the British Museum. Subsequent complete exposure of the included organic remains has brought to light the entire vertebral column of the trunk and tail, to very near the termination of the latter; the scapulo-coracoid arch and part of one fore limb being associated with the thorax, and the iliac bones and both hind limbs with the sacrum.

In the operation of clearing off the matrix, scattered dermal bones first presented themselves, and these were removed, with a note of their position, when it became plain that they did not touch or rest upon any part of the endo-skeleton. This being reached, the dermal bones in contact with it were left, save where they con-

* Volume of the Palæontographical Society for 1859, p. 7, Plates IV, V, and VI.

cealed some joint, process, or other light-giving or characteristic part of the framework. In the course of our operations it soon became evident that the whole vertebral column, in a series of consecutive and but slightly disturbed and mostly coarticulated segments, from the axis to the thirty-fourth caudal vertebræ inclusive, had been raised from their place of deposit; all the parts, save the centrum and a small and low coalesced neural arch, having ceased to be developed, in the terminal caudal vertebræ, the last of which in the recovered series was reduced to dimensions so small as to indicate that but very few remained to complete the tail of the Scelidosaur. The first vertebra of the neck was adherent to the back part of the skull described in the monograph of the Society's Volume for 1859, issued in 1861.

Vertebral Column. Tabs. I—IX.

In the series of Liassic masses following that which included the skull the first four contain twenty vertebræ, extending from the axis to the mass including the sacrum, and clearly consecutive save at one part of the neck.

The back part of the Liassic mass containing the skull of the Scelidosaur includes the atlas vertebra in connection with the occiput, and surmounted by a pair of dermal bones (Tab. I, fig. 1). The block which fits to the fractured surface including the body and the neurapophyses of the atlas contains the axis and third cervical vertebra (ib., fig. 2). The next piece contained one nearly entire cervical vertebra (ib., figs. 3 and 4) and part of a second vertebra. The third, larger, piece contains ten coarticulated vertebræ (Tabs. II and III), but the continuity of the fore part of this mass with the last mentioned cannot be clearly made out. The fourth block fits to that containing the ten dorsals, and includes the five consecutive vertebræ with part of a sixth (Tab. IV). The block which contains the sacrum, has also two vertebræ in advance of it (Tab. VI), part of the first of which lies in the preceding block.

Thus, we have evidence of at least twenty-two "true" vertebræ; but there may have been one or two vertebræ from the region of the neck which have not been recovered. The vertebra attached to the first sacral seems not to have supported ribs; the one in front of it has a pair of long, freely articulated ribs, and may be reckoned the last dorsal. Including this, there may be assigned sixteen vertebræ to the dorsal series, if we include therein the ten vertebræ in Tab. II, leaving six or seven to the cervical series. The lumbar series is thus reduced to one vertebra. The sacrum includes four vertebræ. Of the caudal series thirty-five vertebræ are preserved, in five consecutively fitting blocks of matrix, leaving parts of two terminal ones, so small and simple as to show that very few are wanting in the present fossil skeleton.

The modifications of the spinal column of the trunk and tail of the Scelidosaur can thus be studied and compared in sixty consecutive vertebræ of one and the same individual.

Cervical Vertebræ. Tab. I.

The fracture of the matrix including the skull has passed through the centrum (Tab. I, fig. 1, *c*), hypapophysis (ib., *hy*), and neurapophyses (ib. *n*, *n*), of the atlas.

The centrum of the atlas is small, and has been anchylosed with that of the axis (Tab. I, fig. 2, *x*). The vertical section of it is subquadrate, longitudinally grooved on each side; broader above than below. The hypapophysis (fig. 1, *hy*) is broader, but less deep, than the centrum, and the bases of the neurapophyses (ib., *n*, *n*,) extend down the sides of the centrum to articulate with the hypapophysis.

The neurapophyses (ib., *n*, *n*) are ununited above, as they are below, and have yielded to the oblique pressure; but the slight dislocation seems to have taken place without fracture of an upper union. There is no trace of spinous process; but above the neural arch of the atlas is a pair of large, thick, transversely oblong, dermal bones or scutes; the fractured surface of the most entire one, to the right (ib., *r*) is 2 inches in length by 1 in depth; it exposes a compact peripheral texture of 4 or 5 lines in thickness at the upper and outer part, and about 1 line at the under or inner part, with a fine cancellous structure between. To the broad hypapophysis of the atlas was articulated a long and slender rib (*pleurapophysis*) (ib., fig. 2, *pl*, *a*).

In the foregoing constitution of the vertebral segment succeeding the skull we have the reptilian condition of the atlas, with modifications most closely repeated by the *Crocodilia* amongst the existing members of the class. The *Crocodilia* alone show the transverse extension of the hypapophysis or "pseudo-centrum" of the segment, associated with the presence of articulations for the pleurapophysial elements. In lizards free pleurapophyses are not developed from the atlas or from the axis, rarely from the third cervical vertebra. But in *Scelidosaurus* the atlantal hypapophysis is relatively broader than in *Crocodilia*, and there is no trace of the detached representative of the neural spine which characterises the atlas in Crocodilia.* In Plesiosaurus and Ichthyosaurus the true centrum of the atlas progressively acquires its form and proportions as such, and in the same degree resembles, in its relations to the basi-occipital, and to its own neural arch, the centrum of the first trunk-vertebra in fishes. The hypapophysis is proportionally reduced in size, and forms the first of the "sub-vertebral wedge-bones" in the *Ichthyosaurus*.*

The second block of Lias (Tab. I, fig. 2) includes the bodies of the axis (*x*)

* See descriptions and figures of the modifications of the atlas and axis in my paper on the homologies of those bones in the 'Annals and Magazine of Natural History,' vol. xx, pp. 217—225.

and of the third cervical vertebra (*a*, 3) with parts of the pleurapophyses of the atlas (*pl. a*) and axis (*pl. x*); it includes, also, large, massive dermal bones external and superior to the vertebral elements. The centrum of the axis is 1 inch 3 lines in length, from the line of adhesion of that of the atlas, part of which remains connected, as the "odontoid process;" the proper body of the axis is subcarinate below; gently concave lengthwise at the sides; compressed in the same degree at the middle, and slightly expanded at the extremities. The rib which it supported (*pl' x*) is shorter than that of the atlas, but, like it, is slender and straight; about 3 inches of the atlantal rib is preserved, and about 2 inches of that of the axis.

The body of the third vertebra (3) presents a general increase of size; it is 1 inch 8 lines in length, 2 inches 3 lines across the parapophyses at the fore part of the vertebra, 1 inch 6 lines across the posterior articular surface, and 1 inch 2 lines in depth. It is subcompressed at the sides, and more obtusely ridged below than the axis. The fore part of the body is articulated by an almost flattened surface with that at the back of the axis.

The characters of the terminal articular surfaces are worked out more completely in a consecutive cervical vertebra detached from the third block, and which, from its size, is probably the sixth. The part of the front surface (fig. 4, 6) which is preserved, is flat with a convex periphery; the hind surface (fig. 3, *c*) is slightly concave, with a narrower and better defined circumference. The body of this vertebra is 1 inch 10 lines in length, 2 inches 3 lines across the parapophyses (*p*); 1 inch 8 lines across the hinder articular end (*c*). The under part of the centrum presents near its fore end a hypapophysial tuberosity; it is constricted at the middle, and a small venous canal opens into that concavity on either side. The rib (*pl*) articulates by a bifurcate end with both par- and di- apophyses: the upper transverse process (fig. 4, *d*) extends nearly $1\frac{1}{2}$ inch from the neural arch; the neural canal (*n*) is of a full oval form, with the small end downwards; it is 9 inches in its longest diameter. The breadth of the neural arch, below the diapophyses, is 1 inch 7 lines.

In the portion of the succeeding cervical vertebra, from the same block, the rib is directed more outwardly than in the antecedent one. The length of the neck of the rib is 1 inch 2 lines; its thickness 6 lines, which increases after the development of the tubercle, where the fracture shows a subtriedral section. The portion of the articular surface which is preserved (*b*) of the centrum of the seventh vertebra indicates the same feeble concavity as in the preceding cervical vertebra (fig. 3).

Supposing the vertebra (Tab. I, figs. 3 and 4) to be the sixth of the cervical series, it shows that the rib has more speedily resumed its normal character than in the *Crocodilia*. In these large existing Saurians the pleurapophysis, slender, straight and rather long, in the atlas and axis, becomes shortened and expanded in the third, fourth, fifth, and sixth cervical vertebræ, assuming in them a hatchet-like shape, with an overlapping arrangement; the posterior production of the "blade"

lengthens in the seventh cervical; but the ordinary rib-shape is only resumed in the eighth vertebra, regarded as the first dorsal by Cuvier.

I infer, therefore, from the size and proportions of the two vertebræ just described that they correspond with the sixth and seventh in the Crocodile, and that the Scelidosaurus, with probably other *Dinosauria*, differed from *Crocodilia* and from most *Lacertilia* in the long and slender form of most, if not all, of the cervical ribs; but that these manifested their more essential Crocodilian affinity in their twofold articulation, by a bifurcate head, with distinct upper and lower transverse processes.

The fourth block of Lias includes, with the scapular arch, ten of the anterior dorsal vertebræ (Tabs. II and III). The hinder fracture of the block has detached the anterior articular surface from the eleventh dorsal, the rest of which is the first of the series of the five following dorsals in the fifth block of Lias (Tabs. IV, figs. 1 and 2). The hinder fracture of this block has pretty equally bisected the last vertebra, which bears free ribs, viz., the sixteenth dorsal, the hinder half of which remains in the fore part of the block (Tab. VI), including the lumbar and sacral series of vertebræ. The section of the eleventh dorsal thus exposed near the anterior articular surface of the centrum is represented of the natural size in Tab. V, fig. 1, D 11. That through the middle of the sixteenth dorsal vertebra is similarly represented in Tab. V, fig. 2, D 16.

The spinous process of the first dorsal vertebra (Tab. II, D 1) is $1\frac{1}{2}$ inch in height and 8 lines in fore-and-aft extent; the spine increases in both directions to the fifth of these vertebræ (5), which is 2 inches 4 lines in height and 1 inch 10 lines in basal extent. The spines continue of about the same height to the tenth vertebra, D 10, with summits obtusely rounded, almost truncate. In the eleventh to the sixteenth dorsals, Tab. IV, D 11—D 16, the spines acquire their greatest fore-and-aft extent, with truncate summits, but no increase of height. Although these spines in the last six vertebræ are nearly $2\frac{1}{2}$ inches in antero-posterior extent, their summits do not come into contact, but leave interspaces of from 5 lines to 8 lines.

The prezygapophyses in the anterior dorsal vertebræ look inward and a little upward, the postzygapophyses in the reverse directions, but as the vertebræ recede in position the aspect of the surfaces becomes more nearly horizontal (Tab. V, fig. 1, *z*). The diapophyses are subdepressed, 10 lines in breadth in the second vertebra, and gradually increasing to a terminal breadth of 15 lines in the ninth and tenth dorsals Tab. II, *d*, *d*. The parapophyses, as in the Crocodile, gradually pass from the centrum to the neural arch, and are seen at *p*, fig. 1, Tab. V, upon the under and fore part of the diapophysis (*d*) in the eleventh of this series of dorsals, where the length of the diapophysis from the base of the neural spine is 2 inches 9 lines. No trace of parapophysis, or of the "head" of the rib, remains in the last three dorsals; the diapophysis is entire, as at *d*, fig. 2, Tab. V.

The ribs of the twelve anterior dorsal vertebræ show both the head and the tubercle, the neck becoming gradually shorter in the last three. In the seventh vertebra the extent of the rib from the head to the tubercle is 2 inches 9 lines. In the tenth vertebra it is 1 inch 7 lines. The rib presents a shallow canal along its posterior surface; it is nearly an inch in thickness. An extent of upwards of 10 inches of the body of the rib (*pl.*, Tab. II) is preserved on the right side of this portion of the thorax of *Scelidotherium*.

The anterior dorsal vertebræ have been partially dislocated, especially the fourth from the fifth, apparently by pressure acting through the scapula (51) upon the diapophysis and spine of the fifth dorsal. Beyond the scapula the vertebræ have retained their natural position and connections, which seems to indicate the action of pressure whilst decomposition of the soft parts was going on in the carcass. Nine of the consecutive vertebræ in the fourth block occupy the extent of 1 foot 9 inches. The breadth of the last of these vertebræ (Tab. II, D 10), across the diapophyses (*d*), is 5 inches 4 lines. The total height of the eleventh dorsal vertebra (Tab. 5, fig. 1) is 6 inches. The breadth of the centrum at the fractured part, near the anterior surface, is 1 inch 6 lines. The depth of the centrum, from the floor of the neural canal, is 2 inches. The breadth of the neural arch across what are called the "pedicles," is 1 inch 8 lines. The height of the neural spine is 2 inches 6 lines.

As the vertebræ approach the sacrum the bodies gradually increase in depth, without gaining in breadth, until at the last dorsal the centrum, near its middle part, measures $2\frac{1}{2}$ inches in vertical and 1 inch 7 lines in transverse diameter; a slight longitudinal impression on each side produces the contour of the transverse vertical section figured in Tab. V, fig. 2. The neural canal here gives a triangular section, with the apex downward and sinking into the substance of the centrum, but the sutural limit between centrum and neural arch are indiscernible. The diapophyses decrease in breadth and also in length, and now support the rib by a terminal, slightly notched, articular facet. The ribs, here with simple heads, become shorter and less curved; a few, as in Tab. IV, fig. 1, *pl*, have suffered fracture, with very little displacement. In different parts of the matrix of the blocks (Tabs. II and IV) are portions of long and slender bones, which are, most probably, abdominal ribs.

In the sixth block the hinder half of the last dorsal and one lumbar vertebræ are associated with the pelvis; the lumbar vertebra (Tab. VI, L) had been dislocated downwards from its articulations with the sacrum.

The four vertebræ of this part (Tab. VI), with the iliac bones (62), are preserved almost in their natural relative positions, the sacral vertebræ having their neural spines and transverse processes exposed. Those of the first sacral (S1, *d*, *pl*) stand out horizontally and transverse to the axis of the body; a slight swelling (*d*), about one inch from their origin, may indicate the point of confluence of the pleurapo-

physial (*pl*) with the par- and di- apophysial elements of this part. It is $4\frac{1}{2}$ inches in length; at its base it is 1 inch in thickness and 2 inches in depth, expanding in that direction to fully 3 inches at the truncate extremity, and in breadth to 2 inches 2 lines. Towards its end the process is excavated anteriorly, so that the rough terminal surface (fig. 2, *pl.*) abutting upon the iliac bone is reniform. Fracture of an angle of this surface in the left transverse process shows a medullary cavity of 10 lines in diameter by 6 lines in the section as exposed, surrounded by a fine cancellous, almost compact, osseous texture, of from 2 lines to 4 lines in thickness.

The transverse processes of the other sacral vertebræ gradually become shorter, with corresponding decrease of breadth at their origin, but with equal or greater expansion of their termination, that of the last (*pl*, *s* 4) measuring 2 inches 7 lines in fore and aft breadth; the transverse processes thus touch each other, or nearly so, at their ends, and offer a continuous longitudinal surface for the ligamentous or fibro-cartilaginous attachments of the iliac bones (62). The total length of the articular "sacro-iliac" tract, so formed, is about 10 inches; a very slight lateral twist or dislocation makes it rather longer on the left than on the right side; this appears to have been due to great pressure after imbedding, and is accompanied by fracture or dislocation of the pleurapophysial part of the transverse process of the last two sacral vertebræ.

The spinous process, in each of the four sacrals, is about 2 inches high and 2 inches 3 lines in fore and aft extent: they touch each other by their rough, flattened summits; these are narrow anteriorly, gradually expanding to a breadth of 8 lines at their posterior third, with a thick, rounded termination; the position of these spines is over the interspaces of the origins of the transverse processes, through the backward inclination or extension of the neural arches. The articular processes are faintly indicated at their base, the posterior processes overlapping the anterior ones of the succeeding vertebra. The longitudinal extent of the truncated summits of the four sacral spines is 9 inches.

The hinder fractured surface of the block containing the sacrum exposes part of the first caudal vertebra, the rest being associated with the four consecutive caudals in the seventh block of Lias (Tab. VII, figs. 1 and 2).

The first caudal vertebra has been dislocated from the last sacral, and twisted half round, so that its spine lies upon the sacral transverse process; the fracture has passed through the spine and part of the neural arch. The length of this spine (Tab. VII, fig. 1, *ns*) from the upper part of the neural canal is 3 inches 6 lines, the transverse process (*d*) is 2 inches 3 lines in length, but its vertical thickness is reduced to 5 lines at 2 inches from its termination. The neural canal is 6 lines in breadth and 10 lines in depth. The bases of the neural arch seem to show that the anchylosis with the centrum had not here been complete.

The length of the first caudal centrum (Tab. VII, *c* 1) is 2 inches, the depth or

vertical diameter of its articular end is 2 inches 5 lines; the surface is moderately concave, with the circumference bevelled off convexly; between the two expanded ends the centrum is moderately and uniformly concave lengthwise. There is no trace of hæmal arch in the first caudal. In the second that arch (Tab. VII, fig. 2, *h*) is articulated to the posterior part of the under surface, and is produced into a spine of nearly 4 inches long. In the third caudal (ib., *h*, *c* 3) and succeeding ones the hæmal arch has been dislocated, showing its articular surface, which, by mutual union of the hæmapophysial bases, is single, sub-reniform, transversely extended, lightly concave across, and convex from above downward. The hæmal canal, thus circumscribed, and well shown in the fourth caudal vertebra, is about 2 lines in breadth and 1 inch 3 lines in length; too narrow, it would seem, for the protection of the trunks of the blood-vessels supplying so long and so powerful an organ as the tail of the *Scelidosaurus*. This form of the hæmal canal or slit has every appearance of being natural, and not due to any posthumous compression. The hæmapophysial surface external to it is convex transversely, slightly concave lengthwise; the laminæ slightly contract to their union in the spine, which becomes compressed, and a little expanded from before backwards near its termination. The articular surface, after the second hæmal arch, is afforded in equal proportions by the two conjoined centrums beneath their terminal junction. The transverse process of the second caudal (ib., *d*) arises from the anterior two thirds of the vertebra, over the junction of the centrum with the neural arch; a trace of the suture indicating the pleurapophysial character of this process is discernible in this and some following caudals. The length of the centrum is 2 inches 2 lines; the fore and aft breadth of the base of the transverse process is 1 inch 5 lines; its length is 2 inches 5 lines; its terminal breadth is 10 lines, ending obtusely. The transverse processes progressively decrease in all these dimensions in the following vertebræ. The anterior zygapophyses (Tab. VII, fig. 1, *z*) are twice the length of the posterior ones (*z'*), by which their extremities are overlapped. The fore and aft breadth of the neurapophyses between these processes is 1 inch 2 lines; that of the summit of the neural spine is 1 inch 6 lines; the height of the spine from the base of the prezygapophysis is 3 inches 4 lines. These dimensions are taken from the third caudal vertebra. The five consecutive and coarticulated anterior caudal vertebræ in the present block of Lias give a collective longitudinal extent of 12 inches. The distal half of the right femur (Tab. VII, fig. 2, 65), and parts of the right tibia (ib., 66) and fibula (ib., 67), are cemented to the vertebræ by the matrix. Figure 1 in this plate gives a side view, fig. 2 an oblique under view, of the first five caudal vertebræ.

The succeeding (eighth) block includes the five vertebræ (Tab. VIII, fig. 1) next in succession. In these the length of the centrum continues to be a little over 2 inches, but they gradually decrease in other diameters, and especially in the

size of their diverging parts. The neural spine, in the ninth, is reduced to 2 inches 5 lines in length; the transverse process (ib., fig. 1, *d*) to 1 inch 3 lines. The hæmal arch and spine retain a length of 3 inches 3 lines. That of the seventh vertebra (fig. 1, *h*) has a basal diameter of 1 inch 1 line, decreasing to 6 lines at the end of the neural canal, and thence to a terminal diameter of $2\frac{1}{2}$ lines, the fore-and-aft diameter being here 10 lines. The centrums progressively become more concave and compressed between the articular ends. The prezygapophyses (ib., fig. 2, *z*) have their articular surface turned more inward, and grasp, as it were, the shortening rudiments of the post-zygapophyses, the neural arch progressively contracting in breadth. The collective length of the five vertebræ in this block is 11 inches.

The ninth block of Lias contains the five succeeding caudals (Tab. VIII, fig. 3). The centrums, exposed at their under and lateral parts, are singularly crushed, the sides of each having been pressed into the substance; yet, where the cracks of the matrix expose the texture of the centrum, as in the fifteenth caudal (Tab. V, fig. 3), it shows a fine, compactly cancellous structure throughout; there is no trace of any such vacuity or unossified nucleus of the centrum as is met with in the vertebræ of *Poikilopleuron*, for example. The centrums retain their length of 2 inches. The hinder articular end of that of the tenth caudal (*c*) adheres to the fore part of the present block. In the next coarticulated vertebra, which is the eleventh of the caudal series (Tab. VIII, fig. 3, 11), the prezygapophysis (ib., fig. 4, *z*) is 10 lines in length and 3 lines in breadth; the neural spine, measured from the base of the zygapophysis, is 2 inches in length; the transverse process (fig. 3, *d*) is 1 inch in length, with half an inch of basal breadth. Nearly $2\frac{1}{2}$ inches of the hæmal arch (ib., *h*) are preserved.

The pressure crushing the centrum of the eleventh vertebra has been applied to the middle of the under and lateral part; the articular ends have withstood, if they have received, it. The same is the case with the twelfth caudal. In the thirteenth the pressure has been more laterally applied, and the outer wall, which has been driven in, preserves its vertical convexity. The diapophysis of this vertebra is 10 lines in length. In the fifteenth caudal (ib., 15, *d*) the diapophysis is reduced to 6 lines in length, with corresponding decrease of thickness. The five caudal vertebræ from the eleventh to the fifteenth inclusive occupy a longitudinal extent of 11 inches 6 lines.

The tenth mass of Lias, fitting on to the foregoing, includes a consecutive series of nine vertebræ, viz., the sixteenth to the twenty-fourth caudal inclusive (Tab. IX, fig. 1). In this series there has been a dislocation of the eighteenth from the nineteenth, and a similar one between the twenty-first and the twenty-second vertebræ, with an interval of nearly an inch between the separated articular ends of the centrums. These elements continue to decrease in vertical and transverse diameters, and also, but in a minor degree, in regard to their length.

The transverse process has subsided to a tubercle upon the eighteenth (ib., fig. 1, *d*), and the postzygapophysis to a notch at the back part of the base of the neural spine, but the prezygapophysis (*z*) continues long and slender throughout this series. The neural spines progressively narrow and shorten, with a backward inclination. The base of the hæmal spine (*h*) of the sixteenth caudal measures 9 lines; its articular surface is transversely oblong. The surface for the articulation of the hæmal arch, from this part of the tail onward, is chiefly afforded by the hinder and under part of its own vertebra, as in fig. 3, *h*. The hæmal arch and spine becomes reduced in the eighteenth caudal to the length of its centrum; and in the twenty-third becomes shorter than the centrum, with a greater degree of antero-posterior expansion of the spine in proportion to the length of that part (ib., fig. 1, 23, *h*). The transverse diameter of the anterior articular surface of the nineteenth caudal is 1 inch 6 lines. The middle of the centrum has been reduced by pressure, attended with some fracture of the outer surface, to a diameter of 7 lines. In some of these vertebræ the middle, crushed parts of the centrum have been severed from the terminal articular expansions. I conclude, therefore, that they have been subjected to a general compressive force, probably connected with the change in the vertical relative position of the stratum. The compact layer of osseous tissue forming the articular end has resisted the pressure; the intervening, intermediate, cancellous structure has yielded to it.

From three smaller portions of the matrix, succeeding the ninth block, eleven consecutive caudal vertebræ were wrought out, as in Tab. IX, fig. 2, making us acquainted with a total of thirty-five caudal vertebræ of *Scelidosaurus*. In the last of this series the centrum (ib., 35) is reduced to the length of 1 inch, and the breadth of its front articular end to 6 lines. In the twenty-fifth caudal vertebra the centrum (ib., fig. 3) is 1 inch $10\frac{1}{2}$ lines in length, 1 inch 3 lines across the articular end, $7\frac{1}{2}$ lines across the middle, the longitudinal concavity of the sides exceeding that of the under surface. At the fore part of this surface the hæmapophysial articulation is barely indicated; at the back part it is marked by two surfaces (*h*), towards the most prominent part of which short, low ridges diverge. The low neural arch has coalesced with the upper three fourths of the centrum; the prezygapophyses (*z*) overhang the free fore part of the centrum, and extend beyond it to clasp the back part of the preposed neural spine. This is represented by a short, compressed ridge projecting above the part clasped by the prezygapophyses. The hæmal arch of the twenty-fourth caudal (ib., fig. 2, 24, *h*) underlies the centrum of the twenty-fifth; it presents a length of 1 inch 6 lines. Its closed base (ib., fig. 4) has a breadth of $7\frac{1}{2}$ lines; it presents a sub-bilobed form, concave transversely, convex from before backward. At the sides of the hæmal canal or rather slit, the arch has a fore-and-aft breadth of 4 lines, the spine expands to twice that extent, with an obtusely rounded termination. In the twenty-seventh caudal vertebra

the hæmal arch and spine are reduced to a length of 1 inch 2 lines; the spine progressively decreases to the thirty-second vertebra, beyond which the hæmal element ceases to be developed.

The centrum of the twenty-seventh caudal (Tab. IX, fig. 5, 27) is 1 inch 10 lines long; the anterior surface is 1 inch in depth, 1 inch 2 lines in breadth. The coalesced base of the neural arch has an extent of 1 inch; the prezygapophyses (*z*) are 9 lines in length; the neural spine (*n s*) is 1 inch in length above the zygapophysial surfaces, its summit penetrates the base of a superincumbent dermal bone, and the hæmal spine (*h*) has a similar relation to the dermal bone below. But both dermal bones may have been pressed nearer to the vertebra than in the living animal as the soft parts became dissolved away. The thirty-second caudal vertebra is 1 inch 4 lines in length, with a terminal breadth of 9 lines and a middle breadth of 6 lines. Its neural surface, showing the coalesced neural arch (*n*), from which the processes have been broken away, is figured in Tab. IX, fig. 6, the hæmal surface is represented at fig. 7, with the last hæmal arch (*h*), which is not quite closed above. The thirty-fourth caudal vertebra (ib., fig. 8), is 1 inch 2 lines in length; the breadth of its front articular end is 7 lines. The anchylosed neural arch has a basal extent of 9 lines; it is convex across the middle, like a saddle, rising into a short pyramidal process (*n s*) behind, like its peak; and still giving off the pair of long and slender prezygapophyses (*z*) from its fore part, which clasp the spine or peak of the antecedent vertebra.

The thirty-five caudal vertebræ, of which the principal distinctive characters have been above described, give a total length of 5 feet 8 inches 3 lines. The extent of dislocation between a few of these vertebræ would make a deduction of about 2 inches from the above extent; but the few vertebræ missing from the end of the tail, and reduced, as shown by parts preserved, to slender centrums, may, probably, have carried the length of the tail to about 6 feet.

The trunk-vertebræ include, as has been shown, four sacral, one lumbar, sixteen dorsal, and seven, or at least six, cervicals, and these vertebræ average each a length of 2 inches: the total length of the vertebral column of the trunk, estimated as including twenty-eight vertebræ, would be, on the above average, 4 feet 8 inches, or, allowing for intervertebral soft parts, 5 feet at the utmost in the recent animal.

The length of the head can scarcely have exceeded, more probably fell short of, 1 foot.

Thus we obtain an approximate estimate of the total length of the individual affording the before-detailed osteological characters of *Scelidosaurus* as not exceeding 12 feet from the snout to the end of the tail. But detached fragments of the fossilized skeleton of other individuals from the Lower Lias of Charmouth indicate a larger size, and that the present is not that of a mature Scelidosaur.

In the general osteological characters of the vertebral column we find this genus agreeing with *Hylæosaurus* and *Teleosaurus*.

None of the anterior vertebræ present the opisthocœlian modification characteristic of the Crocodilian genera *Streptospondylus* and *Cetiosaurus*, and in a minor degree of the Dinosaurian genera *Megalosaurus* and *Iguanodon*.

Not any of the anterior dorsal vertebræ developes the spinous process of so disproportionate a length as they present in the carnivorous *Megalosaurus*. Although the neural arch becomes loftier than *Crocodilia* in the dorsal region of the spine, the exterior of the peduncles or neurapophysial laminæ does not present the complex configuration produced by the strong, oblique ridges underpropping the diapophysis in *Iguanodon* and *Megalosaurus*. Upon the whole, I find the closest agreement to be between *Scelido-* and *Hylæo-saurus* in the characters of the vertebral column; and I infer for both, but especially for *Scelidosaurus*, a greater aptitude for swimming than in the larger *Dinosauria*.

Scapular Arch and Limb. Tabs. II and III.

The scapular arch has been compressed transversely to a degree which has produced fracture of the right coracoid (Tab. II, 52′), without material displacement in its relations to the left (Tab. III, 52 and 52′), but with corresponding approximation of the two scapulæ (Tabs. II and III, 51 and 51′), which have squeezed together, with some fracture and more dislocation, the interposed parietes of the thorax. The right scapula (Tab. II, 51) is least displaced; it extends along the first seven dorsal vertebræ, overlapping the spines of the last two. It is long and rather narrow; thickest above the humeral articulation, narrowest at its middle part, becoming broader and thicker towards its free end or dorsum, which describes a moderate and regular convex curve. The length of the bone to the fore part of its coracoid end is 13 inches; its least breadth is 2 inches; that of the base is 4 inches 10 lines. The body of the scapula describes a slight convexity outward in its course to the humeral joint, the expanded portion in front of which is gently excavated for a triangular space 4 inches long; the apex being upward, with a well-defined boundary, indicative of the attachment of a muscle to this part. The anterior border is almost straight through three fourths of its extent from the base, then becomes slightly concave to the anteriorly produced angle of the coracoid end. The posterior border is more deeply concave, through the production of the thickened part of the bone to form the humeral articulation (Tab. III, *h*). So much as is exposed of this surface is slightly concave transversely, slightly undulating in the opposite direction, 2 inches in breadth. The articulation (*c*) with the coracoid is a straight harmonia. At the upper part of the

humeral articular process there is an oblong notch, with slightly raised borders. The left scapula (Tab. III, 51) has yielded in two places to the external pressure, but without separation of the broken parts. It gives the same indication of the triangular muscular surface on the outside of its distal end as does the right scapula, the apex being defined by a better preserved, slightly raised, obtuse border. The fore part of the acromial end of the scapula (*a*), though fractured like that on the right side, is here better preserved, and gives a breadth of nearly 6 inches to this end of the bone. The humeral articulation (*h*) measures 2 inches 6 lines, the coracoid one (*c*) 4 inches. A small, oval, dermal bone (*d*), 1 inch 6 lines by 1 inch 3 lines, overlies the fore part of the scapulo-coracoid harmonia. It is flattened, slightly convex externally, like some others that seem to have defended the skin of the under surface of the trunk.

The coracoid (ib., 52) is an almost circular, flattened, discoid bone, 5 inches in antero-posterior diameter and 4½ inches in transverse diameter; the margin is most modified where it is expanded in 2 inches of its extent to contribute the coracoid portion (*h*) of the humeral joint. The scapular articular border (*s*) presents less thickness. The mesial or sternal border (*m*), continuing the circular curve, touches its fellow (52′) by only a small part of its circumference. The average thickness of the coracoid plate is 7 lines. About 1 inch 3 lines from the scapular surface there is a foramen, 5 lines in diameter. The free border of the entire coracoid appears to be raised, but this is due to the included surface having been crushed in and cracked by external pressure.

In the hinder interspace of the coracoids there is a flattened mass of a rhomboidal form, composed of scattered portions of thin, dark, osseous substance, cemented together by matrix, which is discoloured by carbonaceous material. No part shows the continuous, roughened, but compact, structure of the dermal bones. It appears rather to be the remains of some partially ossified element of the endoskeleton. In its position it corresponds with the sternum. There is a fainter trace of the same kind of material, or discoloration of the matrix, at the anterior interspace of the coracoids.

The humerus, which is preserved on the left side (Tab. III, 53) has been singularly crushed and flattened; the side of the middle of the shaft being broken away, exposes a small medullary cavity. The distal end (*d*) is broken off, and slightly overlapped by the shaft (53). The length of the humerus is 11 inches 3 lines. It presents a sigmoid flexure, the distal end slightly bent downward or forward; the proximal articulation, moderately convex, is 3 inches 8 lines in the long diameter; the fore part is produced into a strong ridge, here partly broken away. The distal end is 5 inches across, and is moderately concave transversely behind. An osseous tubercle, 1 inch 4 lines by 10 lines, is cemented to the anconal surface; a second similar bone is attached to the inter-

space between the inner condyle and the slightly dislocated ulna. These are more probably parts of the scattered dermo-skeleton than tendinal sesamoids of the extensor of the forearm

The acromial end of the ulna (Tab. III, 55) presents a convex border 2 inches 2 lines in breadth. The mutilated head of the radius (ib., 54), preserving its natural relations to the outer condyle of the humerus, is 1 inch 6 lines in length.

The shafts of the radius and ulna, with the rest of the bones of the fore limb, have been broken away.

Four oval, dermal bones, like those overlying the humerus and ulna, are attached to the matrix in front of the humerus and radius.

Behind the fractured sternal end of the right coracoid (Tab. II, 52) is the dislocated head (53) and anterior expanded pectoral process (*p*) of the right humerus (ib.), showing a thickness of 7 lines where it has been broken off. The transverse diameter of the humerus at this part is 6 inches, with a thickness of the shaft not exceeding 2 inches 9 lines, showing that the humerus in *Scelidosaurus* was more expanded and compressed proximally than in any existing reptile, and in this respect resembling the same bone in the Dicynodonts.

The proportions of the entire fore limb of *Scelidosaurus*, as indicated by the length of the humerus, would be those of the same limb in *Teleosaurus*. The humerus is shorter than the scapula, barely equalling the extent of four coarticulated middle dorsal vertebræ. There is no trace of clavicle in the present specimen; the functions of the fore limb seem, therefore, to have been less important in regard to locomotion on land than in Iguanodon, Megalosaurus, and modern Lizards. Yet the shape and proportions of the coracoid, as I pointed out in regard to the *Stagonolepis* when the remains and impressions of that reptile were submitted to my inspection by Sir Roderic I. Murchison, at Leeds, during the meeting of the British Association, September 24th, 1858,* show the distinction from the Crocodilian order and the affinity to the Thecodontian order and to modern Lacertilia, or give evidence of a more generalised reptilian character, in these extinct reptiles with dermal bones and scutes of the Lower Liassic and Upper Triassic deposits.

Pelvic Arch and Limb. Tabs. VI, X, XI.

The left iliac bone (Tab. VI, figs. 1 and 2, 62) retains almost its natural relations with the sacrum. The right iliac bone (ib., 62) has been obliquely dislocated. It is a long bone, with a sigmoid flexure (ib., fig. 2, 62), convex

* Art. "Palæontology," 'Encyclopædia Britannica,' vol. xvii, p. 130, in which, in reference to the Elgin matrix of *Stagonolepis*, it was stated that "no characteristic Devonian or Old Red fossils of any class have been discovered associated with the foregoing evidences of reptiles, which, according to the determination of strata by characteristic fossils, would belong to the secondary or mezozoic period."

upward and outward in its anterior two thirds, more slightly concave in the rest of its extent. Of the left ilium an extent of 18 inches is preserved, a part, apparently a small one, being wanting from both extremities. The narrowest portion of the bone is that which is produced anterior to the first sacral rib (ib., *s* 1); this portion is 6 inches in extent, triedral in form, 2 inches 6 lines in breadth where it joins the obtuse, expanded end of that rib. Beyond or behind the first sacral abutment the ilium progressively expands to a breadth of about 5 inches opposite the fourth abutment (*s* 4). The thickness of the bone, as exposed in the fracture of the left ilium, is from 2 inches to $2\frac{1}{2}$ inches. The middle third of the substance of the bone shows a rather open, cancellous structure; external to this the texture is much closer, with a compact, peripheral layer of from 1 to 2 lines in thickness. The articular cavity for the femur is on the under and outer side of that part of the ilium which is opposite its symphysis with the first two sacral vertebræ (*s* 1 and *s* 2).

The fore-part of the right ilium (62′), has been thrust away from that junction, and the femur (65) is dislocated, passing beneath the ilium, with the head abutting against the sacrum. The summit of the great trochanter terminates rather more than an inch below the articular head of the bone. The breadth of the femur across this part of the trochanter is 3 inches 6 lines. The length of the femur (Tab. X, fig. 1, 65) is 1 foot 4 inches. The inner process or ridge (*t*) begins to be developed about $5\frac{1}{2}$ inches from the head of the bone, and is 2 inches in extent. The shaft of the bone at this part is rather flattened, both anteriorly and posteriorly, and is most convex externally. It assumes a rounder circumference about 1 inch below the inner process, where the bone is 2 inches 4 lines in diameter. Thence it expands to the condyles (*a* and *b*), becoming flattened anteriorly and concave posteriorly. The condyles are but feebly indicated by a shallow notch on the fore part, but more distinctly behind, where they are produced backward. The hind extremity of the outer condyle (*b*) is marked off by a notch from the rest of its articular surface lying anterior and external to it. This posteriorly defined part articulates with the outer condyloid production of the head of the tibia, the fibula articulating with the rest of the outer condyle. The transversely convex fore part of the shaft of the femur is divided on each side by a low ridge from the flattened surfaces converging towards it, the one from the outer side, the other from the inner process (*t*). The exterior of these ridges is continued further down the bone than the opposite one. This femur, being broken across about 6 inches from its upper end, shows a medullary cavity of about $1\frac{1}{2}$ inch in diameter, with a compact and finally cancellous wall, which is nearly an inch in thickness next the base of the inner process, and is about 3 lines in thickness on the opposite side of the shaft (Tab. X, fig. 2). The transverse breadth of the shaft here is 2 inches 7 lines, the fore-and-aft breadth is 2 inches. The transverse breadth of the distal end is 4

inches 10 lines ; the fore-and-aft breadth of the outer condyle is 3 inches 3 lines, that of the inner condyle 3 inches 8 lines; the depth of the posterior inter-condyloid notch is 1 inch 3 lines.

The proximal ends of the tibia and fibula are crushed below their articular surfaces ; most so in the right leg, with fracture of both bones. The medullary cavity of the right tibia has been obliterated by this violence, and the strong, compact wall broken and crushed in upon it. The fibula, with a smaller cavity and thicker, compact walls, has better resisted the pressure, especially in the left limb.

The length of the tibia (Tab. X, 66) is 12 inches 10 lines, that of the fibula (ib. 67) is about an inch shorter. The expanded upper end of the tibia passes over the outer and part of the front surface of the head of the fibula ;* the expanded lower end of the tibia passes behind that of the fibula, showing a kind of twisted, terminally overlapping relation between the two bones. There is a distinct interosseous space (*o*) between the upper three fourths of their shafts. The breadth of the proximal end of the tibia, which may be a little increased by compression, is 5 inches 6 lines. The breadth of the distal end is 4 inches 6 lines. The tibia, which, on the left side, has suffered least compression at its upper end, and has been partially dislocated from the femur, shows a coadapted surface of very similar shape to that of the femur, convex from before backward, slightly concave transversely at the back part of the joint. In both bones the articular surfaces are rough, as if they had been connected together ligamentously. The tibial articular surface divides posteriorly, as before noted, into two condyloid processes, with an inter-condyloid space of about 2 inches breadth ; one condyle is for the inner condyle of the femur, the other is adapted to the posterior prominence of the outer femoral condyle. The back part of the proximal end of the fibula next the outer condyle of the tibia is similarly produced into a convex protuberance. The fore and outer part of the tibia is produced into a strong procnemial tuberosity or process.

The shaft of the fibula contracts to a diameter of 1 inch 10 lines, and then expands transversely, but without corresponding fore-and-aft enlargement, to the distal breadth above recorded.

To the major part of the distal end of the tibia, at least to two thirds of its inner or tibial side, is articulated the tarsal bone (*a*), including the coalesced homologues of the astragalus, naviculare, with the ento- and meso-cuneiform bones, of the mammalian tarsus. This bone (Tab. X, fig. 1, *a*) presents an anterior surface of an elongated, irregular, triangular form, with the apex tibiad or toward the inner side of the tarsus. It becomes narrower as it proceeds backward beneath the tibia (ib., fig. 3, *a*), its articular surface with which is concave from before backward,

* In their natural relative positions, the fibula has been slightly dislocated outward in the left leg. (Tab. X.)

favouring flexion and extension, or motion of the foot to and fro. Its distal surface is convex in the same direction, and is sinuous transversely.

The calcaneum (ib., figs. 1 and 3, *l*) articulates with the distal end of the fibula (fig. 1, 67) and with the outer third of the same surface of the tibia (fig. 3, *l*).

The next most intelligible tarsal bone is that (figs. 1 and 3, *b*) which articulates with the calcaneum (*l*) and with the two outer metatarsals (*iv* and *v*). Its largest surface is turned forward or upward (fig. 1, *b*). Its posterior surface (fig. 1, *b*) is a smaller convex protuberance; this bone answers to the "cuboïdes."

At the back part of the tarsus there projects the base of a wedge-shaped bone, (fig. 3, *e*) seemingly partially dislocated backward, which mainly supports the middle metatarsal (*iii*), and extends partly over the fourth (fig. 3, *iv*). The apex of this bone appears on the front side of the tarsus (fig. 1, *e*) in the interspace between the astragalus (*a*), cuboïdes (*b*), the third and fourth metatarsals. I regard this bone, therefore, as answering to the ecto-cuneiform; I cannot discern any trace of other cuneiform bones, the fibro-cartilage by which the interspace between the bone (*a*), and the first and second metatarsals, was most probably occupied, held partly the place of the meso- and ento-cuneiform bones. From this it appears that the tarsus of *Scelidosaurus* includes but four bones, as in the Crocodile, Tab. XI, fig. 4. In the Lizard (*Varanus*), fig. 3, an ossification in the fibro-cartilage at the base of the second metatarsal establishes the "meso-cuneiforme," and leaves the "ento-cuneiforme" to combine with the naviculare and astragalus in the bone (*a*).

The metatarsus of *Scelidosaurus* consists of five bones. Of these, the fifth (Tab. IX, figs. 1 and 3, *v*) is abortive, and adherent to a rough ridge on the outer part of the base of the fourth metatarsal, with its proximal half extending over the interspace between that bone and the cuboid to articulate with the latter. It was not, however, flattened and expanded, as in the Crocodile (Tab. XI, fig. 4, *v*), but was slender and styliform, if we may judge by the proximal end which fortunately remains attached in the left hind foot of *Scelidosaurus* (Tab. X, fig. 1, *v*). It most probably did not support a toe, or make any distinct appearance in the entire foot. The other four metatarsals support each a fully-developed toe, with the progressive increase in the number of phalanges characteristic of saurian *Reptilia*; the first having 2, the second 3, the third 4, and the fourth 5 phalanges.

The metatarsal of the first or innermost toe (Tabs. X and XI, *i*), is 2 inches 9 lines long. With its proximal end laterally compressed, and abutting against the corresponding end of the second metatarsal, which is much expanded in that direction. The distal end of the first is 13 lines in breadth, with a convex articular surface. The first phalanx of the toe (*i*) is 2 inches long, 14 lines across the base, convex transversely towards the dorsum of the foot, flattened transversely and slightly concave lengthwise, towards the sole. The ungual phalanx is $1\frac{1}{2}$ inch in

length, and 1 inch in basal breadth; is sub-depressed, and curved downward. About 3 lines in advance of the joint, its breadth is increased by two lateral ridges. The apex is subacute. The under surface is marked by many fine, wavy ridges. There are two obtuse longitudinal prominences on the under surface near the joint, for the advantageous insertion of the flexor tendons, and there is a rough prominence at the middle of the dorsal surface, near the joint for the insertion of the extensor tendon. The dorsal surface near the margins and apex, is sculptured by vascular grooves. The total length of the first digit (*i*) is 6 inches.

The second metatarsal (ib., *ii*) is 5 inches in length; with a proximal articular surface 1 inch 6 lines in breadth, sinuous but almost flat; this surfaee presents almost double the transverse extent in the antero-posterior direction. The inner and anterior part of this surface is produced inward, or tibiad, apparently to afford an abutment or attachment, at least in part, to the proximal end of the first metatarsal. The outer or fibular side of the second metatarsal is almost straight, the inner or tibial one coneave, the expansion at both ends taking plaee chiefly in that direction. The distal articular surface is convex from before backwards, with a median groove produeing a transverse concavity between the two convexities or condyles, at the posterior half; and these slightly project backward. The first phalanx of the second toe is 1 inch 3 lines in length, 1 inch 7 lines across the proximal, and 1 inch 6 lines, across the distal end; the diameter from before backward at the middle of the shaft is 6 lines, the phalanx is consequently broad and sub-depressed. The posterior or plantal surface at the proximal end is slightly produced. The distal articular convexity extends a little way upon the middle of the dorsal surface, and slightly swells out into two condyles at the opposite surface. The second phalanx is much shorter in proportion to its breadth, which at the base is 1 inch 6 lines; the length being 1 inch 7 lines; the tibial border is short and concave; the fibular one is straighter and one third longer. The ungual phalanx (*ii*) differs chiefly from that of the first digit in its superior size, being 2 inches in length and 1 inch 4 lines in its greatest breadth; the fibular margin is convex, the tibial one slightly concave. A side view of the bone, of the natural size, is given at fig. 4, Tab. X.

The length of the third metatarsal (ib., *iii*) is 5 inches 4 lines. It is more symmetrical in shape than the rest. The transverse breadth of the proximal end is 1 inch 8 lines; the fore and aft breadth is 2 inches 1 line. The thickness in this direction diminishes rapidly towards the distal end; the transverse dimension decreases in a much less degree; this, at the middle of the bone, being 1 inch 2 lines, whence it increases to a distal transverse breadth of 1 inch 11 lines. The configuration of this articular surface resembles that of the second metatarsal; the fore and aft breadth of the condyle is 1 inch 6 lines. The proximal phalanx of the third toe (ib., *iii*, 1) is 1 inch 2 lines in length, 1 inch 10 lines across the base,

and 1 inch 3 lines across from before backwards. On the middle of the outer border is a tuberosity; each side of the distal end is deeply impressed; the distal articulation resembles that in the second toe. The greatest transverse breadth of this phalanx is 1 inch 7 lines. The second phalanx (ib., 2), with a basal breadth of 1 inch 6 lines, is only 1 inch 7 lines in length. The distal articulation is 1 inch 5 lines in breadth. The third phalanx (ib., 3), with a basal breadth of 1 inch 3 lines, is 1 inch 2 lines in length, with a distal breadth 1 inch 1 line. The ungual phalanx (ib. 4) is more depressed in proportion to its breadth than that of the preceding toe; in other respects it resembles it in shape.

The fourth metatarsal (ib., *iv*), is 4 inches 5 lines in length, of an unsymmetrical figure, receding from the middle metatarsal along its distal half, which is concave lengthwise on the tibial side; the fibular side presents a general but slighter concavity; this metatarsal is triedral, the fore and back surfaces converging to an obtuse, narrow, outer border, significant of its terminating that side of the foot beyond the representative style of the fifth digit (*v*). The fourth metatarsal measures 1 inch 9 lines across the base and 1 inch 7 lines from before backwards, at the tibial side of the base; the fibular side being reduced to the narrow rough ridge for the ligamentous attachment of the fifth abortive metatarsal. The breadth of the shaft of the fourth metatarsal at its lower third is 1 inch 1 line; that of the distal articular surface is 1 inch 5 lines. The first phalanx of the fourth toe is 1 inch 11 lines in length; the basal breadth is 1 inch 8 lines and the distal breadth is 1 inch 5 lines. The tibial angle of the proximal surface is most produced. The fore-and-aft dimensions of the shaft do not exceed 6 lines. The second phalanx is 1 inch 2 lines in length, and 1 inch 3 lines in basal breadth. The third phalanx is 1 inch in length, 1 inch 4 lines in breadth; the fourth phalanx is 9 lines in length, 1 inch 2 lines in breadth. The ungual phalanx is 1 inch 6 lines in length; 8 lines across its articular surface, 11 lines across its broadest part, caused by the aliform expansions of the bone beyond the articulation. It curves downwards and inwards, or towards the tibial side, to a subacute apex; the characters of its surface correspond with those of the larger ungual phalanges of the preceding toes.

From the abortion of the fifth digit, and the disproportionate shortness of the first, we have in *Scelidosaurus* the example of a reptile manifesting a tendency to the tridactyle type of the hind foot, and this is effected in its remote successor of the Wealden period,—the *Iguanodon*, by the suppression of the first, and by a similar atrophy of the fifth digit. The foot-prints of *Scelidosaurus* would terminate forward by the marks of four claws, the innermost falling short of the base of the second, this and the fourth reaching the same line, and the intermediate third claw extending farthest. The hind foot-prints of *Iguanodon* would be tridactyle.

The total length of the foot of *Scelidosaurus* is 1 foot 1 inch 6 lines; the

length of the leg ('cnemion') is 1 foot; the length of the thigh is 1 foot 4 inches; consequently the total length of the hind limb is 3 feet 5 inches; and, allowing for the fibro-cartilaginous matter of the joints and the terminal claws, the limb may have been 3 feet 8 inches long in the recent animal.

The femur equals the length of about seven co-articulated dorsal vertebræ, and, with the leg, manifests longer proportions to the body than in the *Crocodilia;* but the foot presents shorter and broader proportions although it has the same number of toes. *Scelidosaurus,* however, differs from *Teleosaurus* and modern *Crocodilia* in retaining the ungual phalanx of the fourth toe, as in modern lizards (Tab. XI, fig. 3, *i v*); although it differs from these and resembles the Crocodiles in the non-development of the fifth toe. The interesting evidence of this intermediate relationship afforded by the bones of the hind foot, as by some other parts of the skeleton, is illustrated by the outline figures of the skeleton of the hind foot (Tab. XI) in *Varanus,* fig. 3, in *Crocodilus,* fig. 4, and as similarly restored in *Scelidosaurus,* fig. 2.

In the same plate is figured, of half the natural size, the bones of the right hind foot of the skeleton of the Scelidosaur which has yielded the subjects of the present Monograph; showing the effects of pressure in fracturing and partially dislocating the metatarsal segment, after all the joints of the toes had been cemented by the surrounding hardened matrix in their respective varied numbers and co-adjustment in each toe.

Dermo-skeleton.

The bones belonging to this system were extensively developed in *Scelidosaurus,* and are for the most part of a massive character. They have been much displaced in the present specimen, partly during the decomposition of the carcass, and partly by subsequent pressure due to movements of the imbedding stratum; but retain their most intelligible natural relations to the endo-skeleton in the caudal region: in which part, therefore, I shall begin their description, as they were found, on exposing the vertebral characters on the left side, from the end of the tail forwards; and were either removed, or left *in situ,* as the case required.

At the thirty-first caudal vertebra, for example, there was attached to the back part of the neural arch, and pressed rather obliquely to the left side, an elongated triedral dermal bone, with the narrowest side or surface forming the base, and the two broader or larger lateral surfaces converging at an acute angle to an upper ridge. Much of this ridge on the fore part of the bone had been broken away in the original exposure of the specimen; the length of what remained was 1 inch 2 lines, with a basal breadth of 6 lines. The sides of the bone seemed as if

worm-eaten, by narrow curved grooves with intervening small, oblong, and circular pittings. The texture as exposed by the fracture was compact, reflecting a lustre. Between the twenty-ninth and thirtieth vertebræ there was the basal part of a similarly shaped dermal bone, 1 inch 9 lines in extent, with a basal breadth of 9 lines. It lies upon the right side of the coadopted halves of the neural arches of these vertebræ, but may have been displaced from the median line, and this is more probable as the base of a dermal bone crossing the articulation between the centrums of the same caudal vertebræ, has also been pressed towards the right side, on which the carcass of the reptile appears to have rested in the matrix. But any doubt as to the relations of the dermal bone above indicated was dissipated by the better preservation of those found in connection with the twenty-seventh and twenty-eighth caudal vertebræ (Tab. IX, fig. 2), and which are represented of the natural size in figure 5 of the same plate.

The dermo-neural bone (*d n*), was found fractured, with a slight displacement of the back part of its base: when entire, it had a longitudinal extent of 3 inches 6 lines, and a vertical one of 2 inches. The base is hollow, and has been crushed by the lateral pressure; but seems to have had a breadth of nearly an inch. The sides converge to the upper margin, which describes a bold convex curve from before backwards, along two thirds of the contour, and then descends in a straighter line obliquely backward to the hinder angle of the base. This dermal bone extends from above the prezygapophyses (*z*) of the twenty-seventh caudal vertebra to the fore part of the spine of the twenty-eighth. On removing part of the side of the base of the dermo-neural bone the spine (*n s*) of the twenty-seventh vertebra was seen to have penetrated the basal cavity, as far as that extended into the substance of the dermal bone; but I incline to think that fibrinous or other soluble tissue intervened in the living reptile, and that the position of some of the more anterior dermo-neurals, situated at a higher level above the neural spines, was the more natural one.

The dermo-hæmal bone (ib., *d h*) presents a longitudinal extent of 2 inches 3 lines, with a vertical one of 13 lines, and a basal breadth of about 9 lines. The hæmal spine of the twenty-seventh vertebra (*h*), seems also to have entered a hollow in its base, where it was exposed by removal of part of the left wall of the basal cavity. But this had been pressed up to the under part of the centrums, almost touching the posterior half of the twenty-seventh and the contiguous two thirds of the twenty-eighth caudal vertebræ; obliterating an interspace which should have been occupied by muscle, tendon, ligament, and other soft parts in the recent animal.

The dermo-hæmal spine below the twenty-fifth and twenty-sixth caudals differed only in its larger size from the succeeding one. Part of the base of the corresponding dermo-neural was preserved.

In the series of nine consecutive caudal vertebræ (Tab. IX, fig. 1), the number and disposition of the dermo-neural and dermo-hæmal bones were more fully and satisfactorily exhibited. Three consecutive dermo-neurals extended over a series of seven vertebræ, from near the fore part of the first to near the hinder half of the last of these seven; each extending over the interspaces of two vertebræ. The corresponding dermo-hæmals are of smaller size, cross only one inter-vertebral space, which is the second or posterior of those so crossed above, and their hinder end is a little further back than that end of their homotype above. But, in working out these vertebræ, indications of a third series of caudal dermal bones were first met with. There extended over the articulation between the twenty-first and twenty-second caudals the base of a dermal bone, 3 inches long, crushed, with its apical ridge broken off. On its removal, the vertebræ it crossed were seen to have been displaced to the extent of nearly an inch. The position of this bone, and the ascertained relations of the neural and hæmal dermal bones to their vertebræ, made it improbable that it was one of either of these series displaced; and attention was quickened, which led to the detection of a similar appearance further in advance, to be presently described.

The best preserved dermo-neural, in the series of nine caudal vertebræ (Tab. IX, fig. 1 *d n*), presents a basal longitudinal extent of 3 inches 5 lines, with a basal breadth of 1 inch 9 lines: its *quasi* worm-eaten, rugose sides, converge to an upper margin, not quite entire, but with apparently a contour resembling the dermo-neural in fig. 5. The present larger bone overlies the twentieth and contiguous portions of the nineteenth and twenty-first caudal vertebræ. The corresponding dermo-hæmal bone (*d, h*), with a longitudinal basal extent of 2 inches 6 lines, and a basal breadth of 1 inch 3 lines, underlies the twentieth and twenty-first caudals, extending along a greater proportion of the former. Its sides, similarly but more finely sculptured than the dermo-neural above, converge to a convex inferior border; the depth of the side being not less than 1 inch 6 lines. The next dermo-neural in advance overlies the eighteenth and contiguous half of the seventeenth caudal vertebræ. It presents a basal extent of 3 inches 6 lines, with a basal breadth of 1 inch 6 lines. The base of the corresponding dermo-hæmal spine is preserved, which underlaps the hinder two thirds of the eighteenth and the front third of the nineteenth caudal. Its base is 2 inches 7 lines in length, with a moderate contour. The apical ridge and left side of this bone have been broken away.

Between the above-described dermo-neural and dermo-hæmal bones there was the base of a lateral dermal bone, 3 inches 5 lines in length, applied over the eighteenth and part of the nineteenth caudal vertebræ, like that between the twenty-first and twenty-second. The portion preserved in exposing these vertebræ is figured in the interspace produced by their slight dislocation, into which it

had been wedged by pressure. I conceive it to have been the direct instrument of the dislocation, receiving and transmitting the extraneous pressure; and at a period when the vertebræ in front and behind were sufficiently free in their bed to allow of being pressed close together, with obliteration of their natural interspaces originally occupied by the soft inter-articular material; the extent of such interspace is probably shown between the twenty-second and twenty-third caudals (Tab. IX, fig. 1). From the evidence of the dermo-neurals and dermo-hæmals, *in situ*, in the present series of vertebræ, the dermal bone above described could not be one of either of these series displaced; and I infer from it, and the evidence of a similarly situated bone in a remoter part of the tail, that this appendage was defended by a series of lateral as well of upper and lower dermal ossicles, though, perhaps, in less number, and of a flatter figure, along the sides.

The next dermo-neural in advance overlaps the sixteenth and the contiguous half of the fifteenth caudal vertebræ; but its hinder end, as well as a part of its summit, are broken away. What remains, measures 3 inches 4 lines in length, with a basal breadth of at least 2 inches. The margin of the base of all the above-described dermo-neurals describes a gentle convexity.

As the dermo-neurals advance in position, they progressively acquire increase of basal breadth, to near the base of the tail, retaining the average length of $3\frac{1}{2}$ inches, with a small increase of height. Three dermo-neurals range along an extent of the five vertebræ (eleventh to fifteenth caudals) figured in Tab. VIII, fig. 3; and the same relative number and position are shown in the five antecedent caudals (ib., fig. 1, *d n*).

On the right or imbedded side of the vertebræ, overlying the centrum of the fourteenth, and contiguous parts of the thirteenth and fifteenth vertebræ, is the base of a dermo-lateral bone, 3 inches 3 lines in length, 2 inches 3 lines in breadth, the sides converging at an open angle, but with their terminal ridge broken off. This representative of the lateral series of dermal bones would seem to show that they had greater breadth and thickness than either those of the upper (neural) or lower (hæmal) dermal series. The right side, where these additional indications of a lateral series of dermal bones are preserved, was that which was left imbedded in the matrix; the left side being that which was exposed by the original quarrying operations. It is probable, therefore, that the dermo-lateral bones of the left side, with the exception of the few remains above noticed, were in the matrix so detached. The characters of the caudal vertebræ figured in Tabs. VIII and IX were displayed by careful removal of the matrix left adhering to the parts originally exposed; during which operation the portions of the dermo-lateral bones which had been pressed inward, and contributed to the dislocation of the twenty-first from the twenty-second, and of the eighteenth from the nineteenth caudal vertebræ, were brought to light.

A dermo-neural bone overlies the ninth and tenth caudals (Tab. VIII, fig. 1); another over the seventh and eighth (*d n*); a third over the sixth and fifth. The fracture through the middle of this latter bone (Tab. VII, fig. 3), shows the form and depth of the angular excavation at its base, which rested, probably with interposed ligamentous substance, upon the summit of the neural spine of the caudal. The corresponding dermo-hæmal bones, displaced so as obliquely to overlap the hæmal spines on the right side, are also preserved; and on this side there are as many dermo-lateral scutes, but more fragmentary and dislocated.

In the block of lias with the first five caudal vertebræ (Tab. VII, figs. 1 and 2), is the anterior half of the dermo-neural overlapping the fifth and sixth of that series. Two similar bones with a basal excavation exposed by fracture in one of them, are situated to the right side of the fourth and third caudals, which may be dermo-laterals or displaced dermo-neurals. A portion of a massive dermal bone lies upon a part of the ilium contained in this slab. The rest of the armour of this part of the base of the tail has been removed. The like is the case with regard to the upper part of the block including the sacrum (Tab. VI). At its under part, in which are imbedded dislocated bones of the hind limbs, there are a few scattered portions of wedge-shaped dermal bones, similar in size to those at the base of the tail, but less pyramidal, and with more obtuse summits. A few smaller, flatter, subcircular dermal bones were met with in the course of exposing the parts of the endo-skeleton. One of these (ib., *d*), lies above the interspace between the left ilium and the third sacral rib (Tab. VI, fig. 1, *d*).

In the block of lias containing the fore part of the thorax and scapular arch a longitudinal series of eight dermal bones were found on the right side, overlapping the ribs, external to the diapophyses. These dermal bones were shorter and thicker than the caudal dermo-neurals, and had been subject to more or less fracture and some displacement. The best preserved was wedge-shaped, with the sides of the excavated base slightly convex, 2 inches in length, 8 inches 9 lines in breadth, the sides converging at a more open angle, but unequally, to a margin which shows a convex ridge. The inferior size and unsymmetrical shape of this bone seem to show that it formed part of a lateral row, which had been situated near a middle one, or had ranged along near the medial line of the back. The margins of these bones were not entire. The summit of a dermo-neural spine remains wedged between the spines of the second and third dorsals, and another between those of the fourth and fifth dorsals (Tab. II, *dn*, *dn*). On the left side of the thorax (Tab. III), are preserved some of the upper lateral series of dermal bones (*d n l*), showing their natural position and intervals. On the same side, beneath the foregoing (Tab. III, *d l*) are some larger wedge-shaped dermal bones. Three of these may have been displaced from above the neural spines. They are elliptical; 3 inches long, 2 inches broad at the base, with the sides converging

with a slight concavity to the upper ridge, which has been broken off in each, so that its height is conjectural. Other evidences of dermal bones on the under part of this slab are too fragmentary and scattered to throw any light upon their natural arrangement. On the right side (Tab. II), overlying the ends of the ribs, about ten inches distant from the vertebræ, are preserved three of a series of flattened, sub-ovate, dermal scutes (*d a, d a*), about 3 inches by 2 inches in the long and cross diameters, and from 2 to 4 lines in thickness. The outer surface exhibits the same character of sculpturing as do the dermal bones of the tail; the inner surface is smooth.

In the block containing the second and third cervical vertebræ the pair of lateral, unsymmetrical, dermal bones have been preserved nearly in their natural position. They are three-sided; the shortest is directed towards the intervening vertebræ; the side next in length looks downward; the outer surface, directed upward and outward, is the most extensive. These scutes have been fractured through their centre. They show an external, very compact, layer of bone, thickest on the outer or peripheral side. The rest of the bone shows a rather close cancellous structure. Above these, but slightly displaced, is a pair of wedge-shaped bones, which are probably dermo-neurals, indicative of a parial arrangement of these along the nape, contrasting with their single series above the tail. Each of these dermal bones are somewhat unsymmetrical in form, 2 inches 9 lines in the length of the base, 1 inch 9 lines in breadth, with the median surface more extensive than the outer, and both converging to a ridged summit, but which is broken away.

The anterior pair of nuchal scutes is preserved in connection with the occiput, overlapping the atlas (Tab. I, fig. 1, *dn, r*). They are similar in shape, but smaller in dimensions, than those last described, and have been broken across.

From the sum of the foregoing observations, it may be inferred that the surface of the Scelidosaur was defended by several longitudinal series of massive dermal bones, those occupying the median and upper surface being arranged in pairs upon the nape and singly along the tail. External to these were a lateral series, at least two in number but probably more, on each side the trunk, having the same wedged and ridged shape as the dermo-neurals. Beneath these were flattened, ovate scutes along the lower lateral part of the thoracic-abdominal region. In the tail we have more decisive evidence of a single median row of large, symmetrical, cuneiform, hollow-based, superiorly ridged dermo-neurals, with dimensions making three occupy the space of five vertebræ along the base of the tail, and nearly seven vertebræ along the hinder half of the tail. There was a corresponding median series of smaller and less vertically extended dermo-hæmal bones, and also a single series of dermo-laterals, of more depressed and fuller ovate form, on each side.

The accidents attending the decomposition of the carcass of this reptile seem

to have had the chief share in the removal and displacement of so large a proportion of its coat of mail. Subsequent cosmical violence has been concerned in the fracture, the crushing, and in a certain amount of displacement of the constituent parts of the skeleton. Lastly, further fracture of the fossil bones has been due to the quarrying operations, by which the specimen was brought to light.

Conditions of imbedding and deposit.

The general condition of this almost entire skeleton of a reptile, organized, as seems by the structure and proportions of the hind foot, for terrestrial rather than aquatic life, or at least for amphibious habits on the margins of a river rather than for pursuit of food in the open sea, I infer that the carcass of the dead animal has been drifted down a river, disemboguing in the Liassic ocean, on the muddy bottom of which it would settle down when the skin had been so far decomposed as to permit the escape of the gases engendered by putrefaction. In that predicament the carcass would attract large carnivorous marine fishes and reptiles, and portions of the skin, with prominent parts not too strongly attached to the trunk, would probably be torn away before the weight of the bones had completely buried the carcass in the mud. In this way, perhaps, we may account for the loss of much of the dermo-skeleton and of the two fore paddles. The larger hind limbs with their stronger muscles and ligaments, would offer better resistance to such predatory attacks; and they, at any rate, have been preserved. The agitation to which the body must have been subject in its course down the stream, and before it finally sunk and settled out of sight, would be attended, after a certain amount of decomposition of the flesh, ligaments, and other soft parts, with such an amount of dislocation as the ribs and other parts of the vertebral column exhibit along the otherwise well-preserved and completely consecutive series of the bony segments, from the skull to near the end of the tail. But the oblique compression of the skull, the flattening of the thorax, squeezed between the approximated piers of the scapular arch, attended with fracture of one of the coracoids, and other indications in the rest of the trunk, plainly bespeak the enormous pressure to which the fossil has been subject after its imbedding, and which must have been attended with still more injury and destructive obliteration of anatomical characters had it not been for the surrounding uniform support afforded by the matrix, compactly hardened around the petrified skeleton before those cosmical movements commenced to which the change in the position of the old Liassic sea-bottom has been due.

TAB. I.

Scelidosaurus Harrisonii.

Cervical vertebræ; nat. size.

Fig.

1. Vertical transverse section of the atlas, and of the superincumbent pair of nuchal dermal bones (*dn, r*).

2. Under surface of the axis and third cervical vertebræ, with the ribs of the atlas and axis.

3. Under view of the sixth (?) cervical vertebra, below which is the anterior articular surface of the centrum.

4. Posterior fracture of the same vertebra, showing part of the articular surface of the centrum.

From the upper part of the Lower Lias, Charmouth, Dorsetshire. British Museum.

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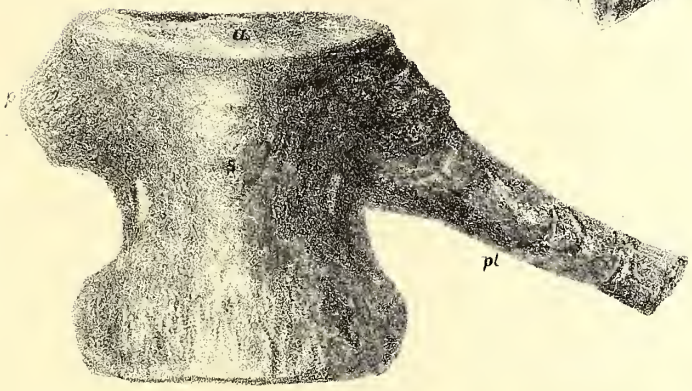

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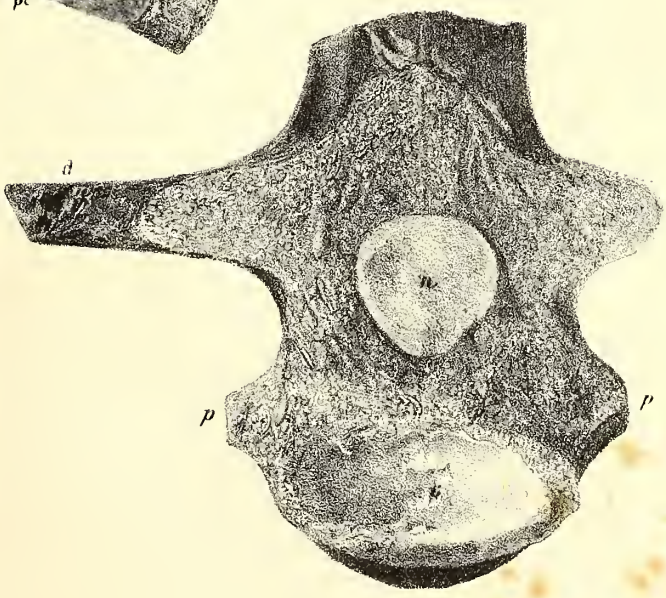

TAB. II.

Scelidosaurus Harrisonii.

Right side of the thorax, with the ten anterior dorsal vertebræ and the scapula; one third nat. size.

From the upper part of the Lower Lias, Charmouth, Dorsetshire. British Museum.

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TAB. III.

Scelidosaurus Harrisonii.

Left side of the thorax and scapular arch, with the humerus and dermal bones; one third nat. size.

From the upper part of the Lower Lias, Charmouth, Dorsetshire. British Museum.

Jos Dinkel del

W. West, imp

TAB. IV.

Scelidosaurus Harrisonii.

Dorsal vertebræ; one third nat. size.

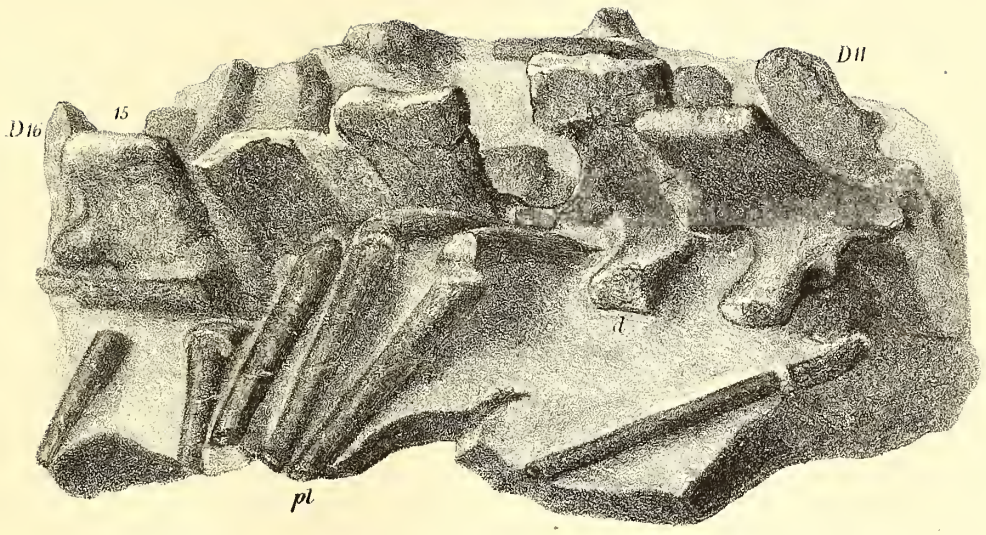
Fig.

1. Right side of parts of the five last dorsal vertebræ.

2. Left side of the same vertebræ.

From the upper part of the Lower Lias, Charmouth, Dorsetshire. British Museum.

1



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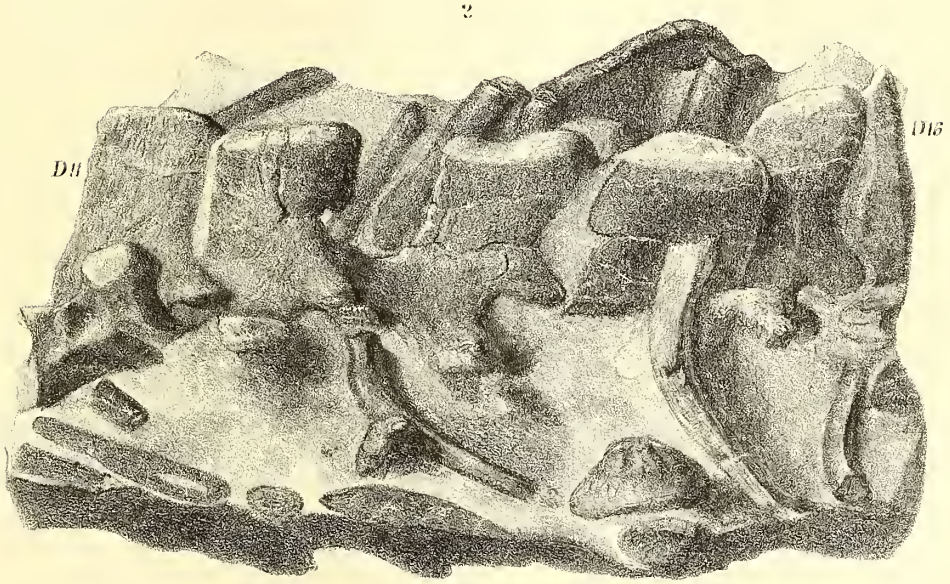


Jos. Dinkel del.

W. West, imp.

TAB. V.

Scelidosaurus Harrisonii.

Dorsal and caudal vertebræ; nat. size.

Fig.

1. Anterior surface, abraded on the centrum, of the eleventh dorsal vertebra.

2. Vertical transverse section of the sixteenth dorsal vertebra.

3. Ditto of the centrum of the fifteenth caudal vertebra.

4. Hinder articular surface of the twenty-eighth caudal vertebra.

From the upper part of the Lower Lias, Charmouth, Dorsetshire. British Museum.

D 11

D 16

TAB. VI.

Scelidosaurus Harrisonii.

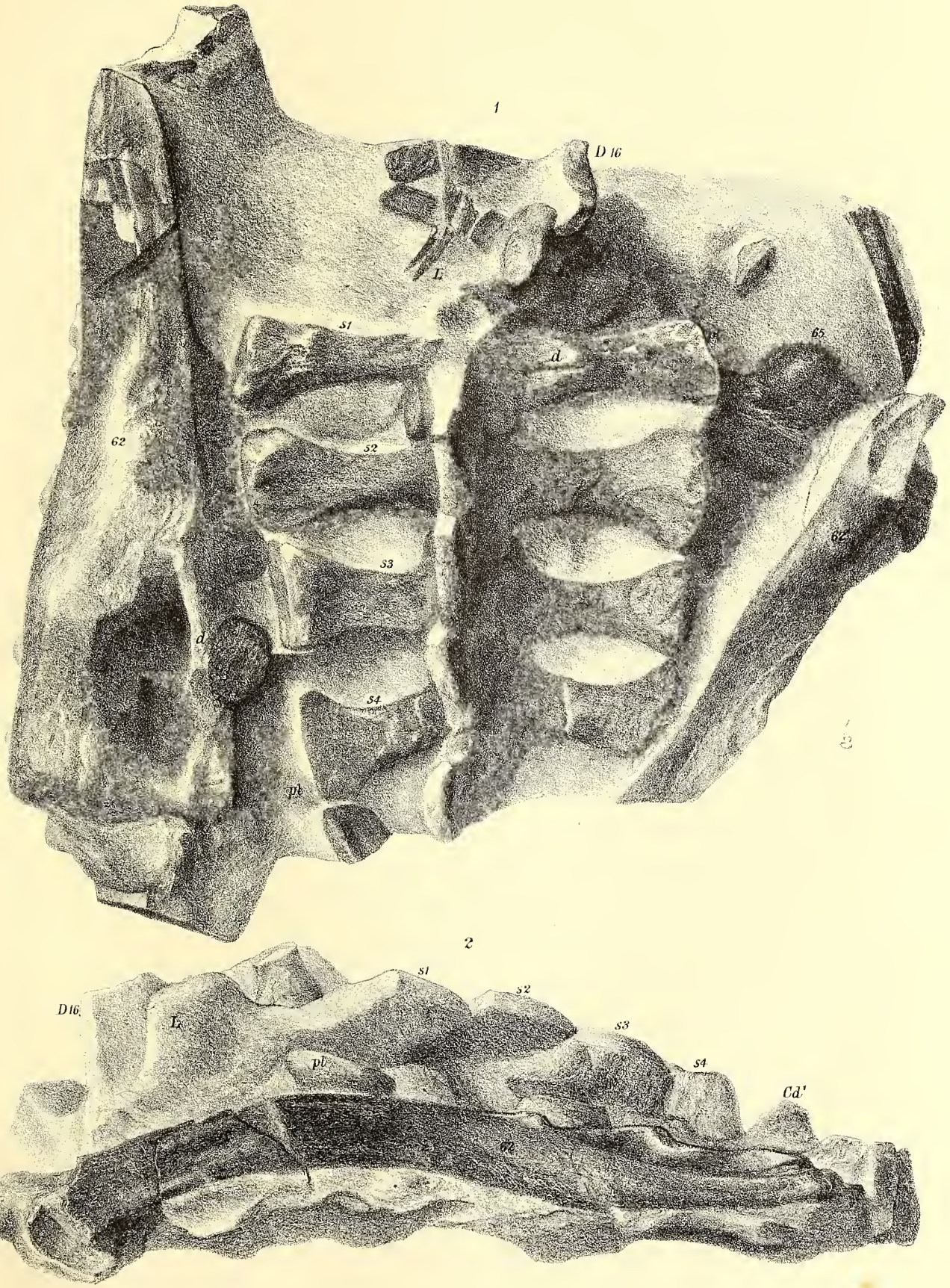
Pelvis; one third nat. size.

Fig.

1. Upper or dorsal view of the sacrum and iliac bones, with the single lumbar vertebra (L) and part of the last dorsal (D 16).

2. Left side view of the ilium and sacrum.

From the upper part of the Lower Lias, Charmouth, Dorsetshire. British Museum.


1
D 16
L
s1
d
65
62
s2
62'
s3
d
s4
pb
2
s1
s2
D16
L
s3
pb
s4
Cd'
62

TAB. VII.

Scelidosaurus Harrisonii.

Caudal vertebræ; one third nat. size.

Fig.

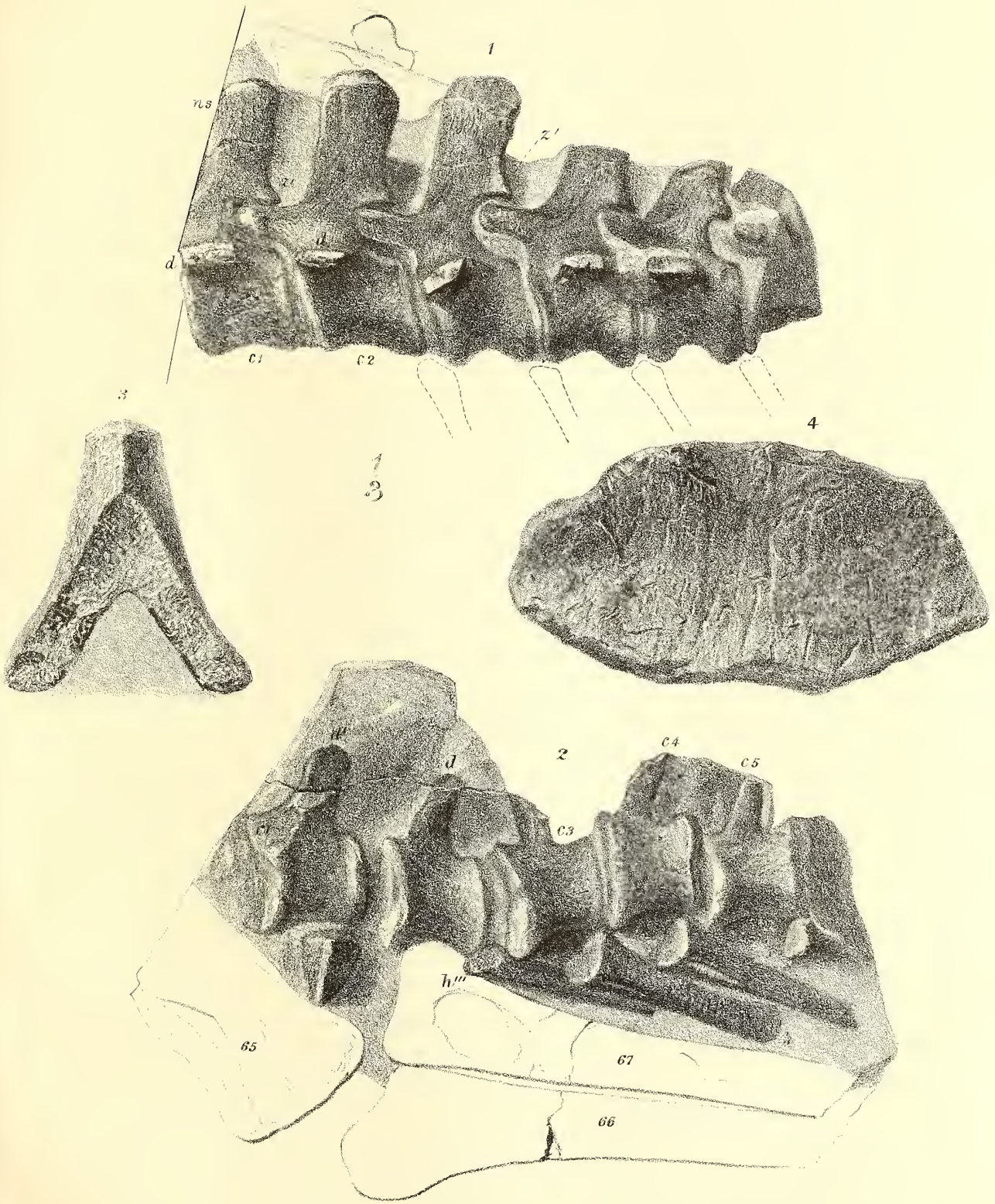
1. Left side view of the first five caudal vertebræ.

2. Oblique under view of the same vertebræ, with outlines of the contiguous limb-bones.

3. Fractured fore part of an anterior caudal dermo-neural bone.

4. Side view of an anterior caudal dermo-neural bone.

From the upper part of the Lower Lias, Charmouth, Dorsetshire. British Museum.


1
ns
z'
d
d'
c1
c2
3
4
1
3
2
d''
d
c4
c5
c1
c3
h'''
65
67
66

TAB. VIII.

Scelidosaurus Harrisonii.

Caudal vertebræ; one third nat. size.

Fig.

1. Oblique under view of the sixth to the tenth caudal vertebræ, and side view of three contiguous dermo-neural bones.

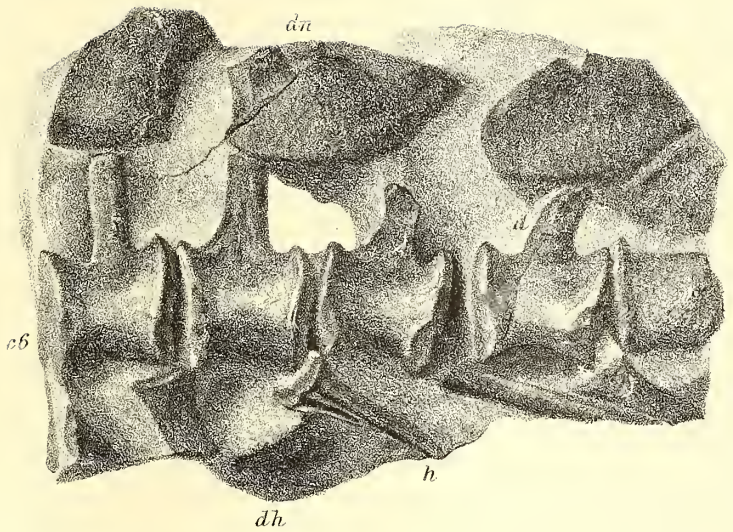
2. Upper view of the ninth caudal vertebra.

3. Oblique under view of the eleventh to the fifteenth caudal vertebræ.

4. Side view of the eleventh caudal vertebra.

From the upper part of the Lower Lias, Charmouth, Dorsetshire. British Museum.

1



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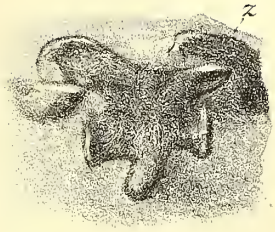

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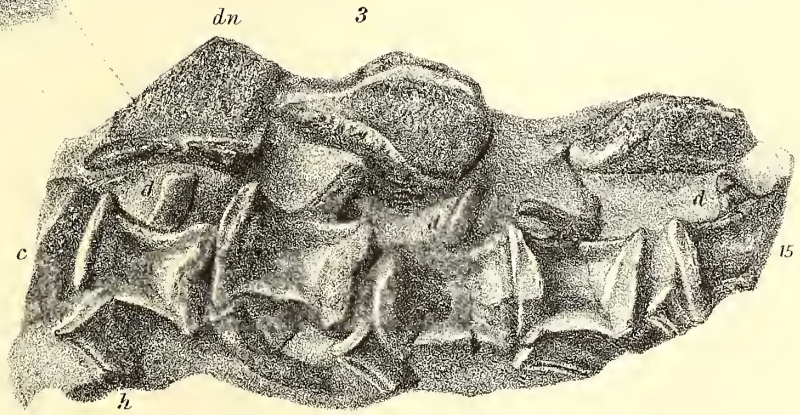


TAB. IX.

Scelidosaurus Harrisonii.

Caudal vertebræ and dermal bones.

Fig.

1. Left side view of the sixteenth to the twenty-fourth caudal vertebræ, with contiguous dermal bones; one third nat. size.

2. Left side view of the twenty-fifth to the thirty-fifth caudal vertebræ; one third nat. size.

3. Under view of the centrum of the twenty-fifth caudal vertebra; nat. size.

4. Articular surface of the hæmal arch of the twenty-fifth caudal vertebra.

5. Left side view of the twenty-seventh and twenty-eighth caudal vertebræ, with their associated dermo-neural (*dn*) and dermo-hæmal (*d*) bones; the anterior articular surface of the centrum of the twenty-seventh caudal vertebra is figured beneath; nat. size.

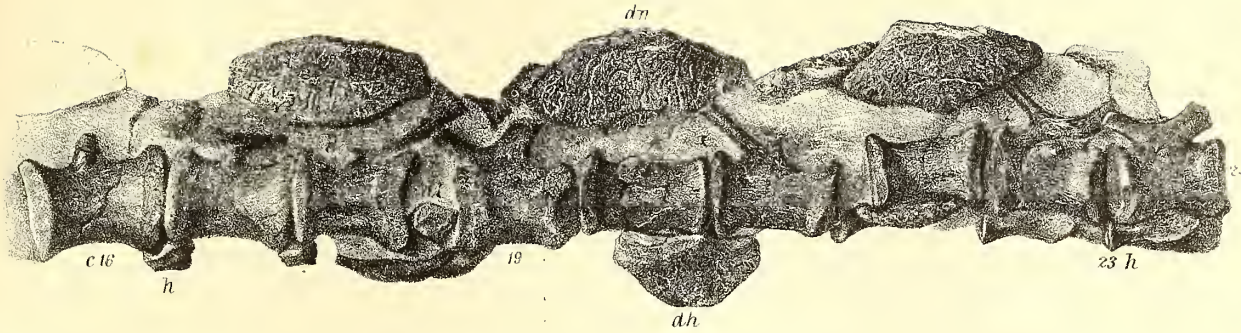
6. Upper view of the thirty-second caudal vertebra.

7. Under view of the same vertebra, with the hæmal arch (*h*).

8. Side view of the thirty-fourth caudal vertebra.

From the upper part of the Lower Lias, Charmouth, Dorsetshire. British Museum.

1



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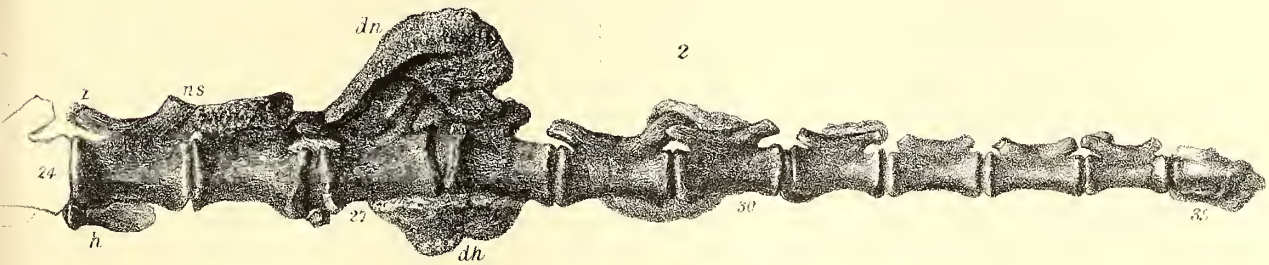

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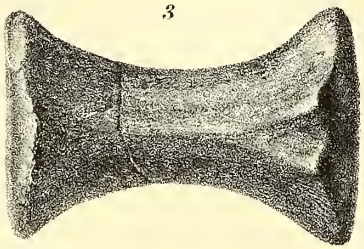

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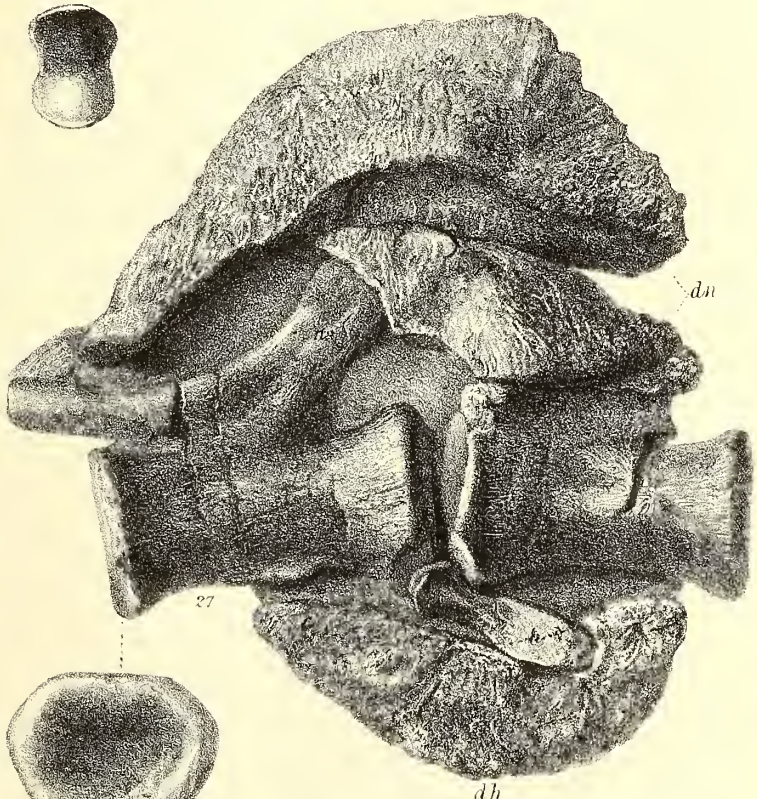

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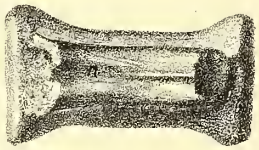

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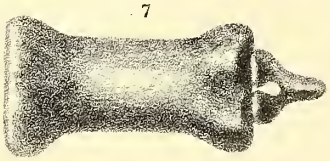

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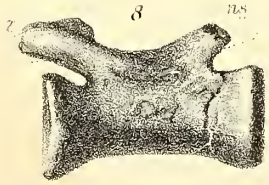


TAB. X.

Scelidosaurus Harrisonii.

Bones of the left hind limb; half nat. size.

Fig.

1. Outer and anterior view of the bones in their natural relative position, as they were exposed in the matrix.

2. Transverse section of the shaft of the femur, showing the medullary cavity; nat. size.

3. Bones of the left hind foot, from the posterior or plantar aspect.

4. Side view of the ungual phalanx of the third toe; nat. size.

From the upper part of the Lower Lias, Charmouth, Dorsetshire. British Museum.

W.West, imp.

Jos Dinkel del

W West, imp

TAB. XI.

Scelidosaurus Harrisonii.

Bones of the right hind foot; half nat. size.

Fig.

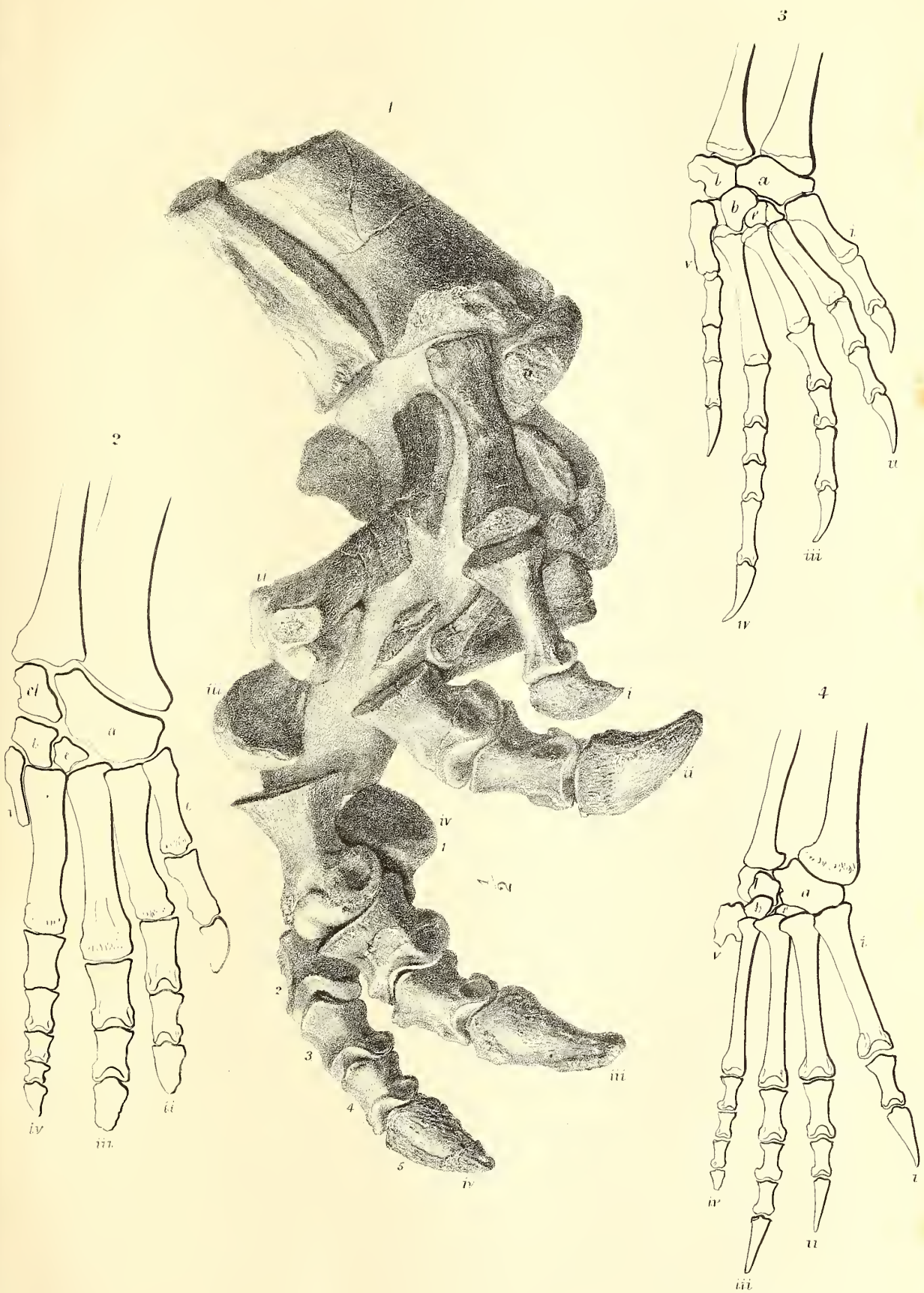
1. Bones of the right hind foot, with the distal ends of the tibia and fibula, showing the amount of dislocation with which they became finally petrified in the matrix.

2. Scheme of the bones of the hind foot, restored.

3. Scheme of the bones of the hind foot of a monitor lizard (*Varanus*).

4. Scheme of the bones of the hind foot of a crocodile (*Crocodilus*).

From the upper part of the Lower Lias, Charmouth, Dorsetshire. British Museum.



s. Dinkel del

W. West imp.

A MONOGRAPH

OF

THE FOSSIL REPTILIA

OF THE

LIASSIC FORMATIONS.

BY

PROFESSOR OWEN, C.B., F.R.S.,

FOREIGN ASSOCIATE OF THE INSTITUTE OF FRANCE,

ETC. ETC.

PART THIRD.

PLESIOSAURUS, DIMORPHODON, AND ICHTHYOSAURUS.

LONDON:

PRINTED FOR THE PALÆONTOGRAPHICAL SOCIETY.

1865—1881.

PRINTED BY
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THE

PALÆONTOGRAPHICAL SOCIETY.

INSTITUTED MDCCCXLVII.

LONDON:

MDCCCLXV.

MONOGRAPH

OF

THE FOSSIL REPTILIA

OF THE

LIASSIC FORMATIONS.

BY

PROFESSOR OWEN, F.R.S., F.L.S., F.G.S., &c.

PART FIRST.

SAUROPTERYGIA.

LONDON:

PRINTED FOR THE PALÆONTOGRAPHICAL SOCIETY.

1865.

J. E. ADLARD, PRINTER, BARTHOLOMEW CLOSE.

MONOGRAPH

OF

THE FOSSIL REPTILIA

OF THE

LIASSIC FORMATIONS.

Order—SAUROPTERYGIA, *Owen.*

Genus—Plesiosaurus, *Conybeare.*

Species—*Plesiosaurus dolichodeirus*, Conybeare.

(Tabs. I—IV.)

Of the *Plesiosaurus dolichodeirus*, Conyb., the first described and the typical species of the genus, three more or less entire specimens have come under my observation, which have been obtained from the Lower Lias of Lyme Regis and Charmouth, Dorsetshire. One of these, formerly in the possession of the late Duke of Buckingham and now in the British Museum, was the subject of Conybeare's original description.* A second, in the British Museum, is figured by Buckland in his 'Bridgewater Treatise,' vol. ii, pl. xix, fig. 2; the third, also in the British Museum, is the one which I have selected for illustration in the present Monograph (Tabs. I and II). In this the vertebral series is entire; there is no break in the long cervical region, as in the other two specimens; its perfection, in this respect, satisfactorily shows that the head is at, or nearly at, the correct distance from the trunk, with the neck outstretched, in the two former specimens, the greater completeness of which, in regard to the limbs, supplies what is wanting in this respect in the present skeleton (see Tab. I, figs. 2 and 3).

The condition of the vertebral column in the originally described or type-specimen of the *Plesiosaurus dolichodeirus* is such as to suggest that the carcass, after it sank to

* 'Transactions of the Geological Society,' 2nd series, vol. i, p. 381, pl. xlviii.

the bottom, had been preyed upon by some contemporary carnivorous marine animals. It seems as if a bite of the neck had pulled out of place the eighth to the twelfth vertebræ. Those at the base of the neck have been scattered and displaced, as if through more "rugging and riving." Some creature which has had a grip of the spine, near the middle of the back, has pulled to one side all the succeeding vertebræ of the pelvis; their adhesion to that part and, more or less, to each other, being retained. This wrench would expose the abdominal viscera, *à tergo,* where we now see the upper or inner surface of the abdominal ribs or sterno-costal arches. The intermediate and succeeding portions of the vertebral column retain their natural relative positions, as in the prone position of the carcass; and the skull, scapular arch and appendages, pelvic arch and appendages, and the tail, show respectively their relative positions as in the entire animal. Many of the otherwise undisturbed vertebræ, however, have turned, so as to present their most extensive surface to the direction of the slow, cosmical, compressing force operating on their imbedding stratum.

This is the case with the first twenty cervical vertebræ in the specimen Tab. I, which appears to have settled in the Liassic mud back downwards, their spines being turned toward the right side; beyond the twenty-first cervical the vertebræ have rotated in the opposite direction, presenting more or less of a side view, with the neural arch and spine turned to the left; but most of the spinous processes have been removed with the matrix in the original exposure of the specimen. The trunk preserves the supine position, exposing the broad coracoids (52), and pubes (64), with scattered, intervening, abdominal ribs. Part of the left pectoral fin (53—56) is *in situ;* a smaller part of the corresponding pelvic fin (65—67) lies across the pelvis.

No partial force has operated after interment to dislocate any of the vertebræ, save the few terminal ones of the tail, which have disappeared, probably dragged away with whatever tegumentary expansion may have there represented a caudal fin.

In the specimen figured by Dr. Buckland * the skeleton, as it is exposed to view, lies prone; the vertebræ, whilst their matrix was in the state allowing them to turn, have presented their largest surface to the direction of superincumbent pressure, the spines of those at the basal half of the neck being turned down or toward the right side, while those of the dorsal vertebræ have yielded in the opposite direction, both kinds presenting more or less of a side view. The thoracic ribs have slipped some way from their articulations, yet preserve, in the main, their relative positions, in serial succession. The anterior dorsals overlie the coracoids, and the posterior dorsal and sacral vertebræ overlie the dislocated parts of the pelvis. One of the thickened, short, and straight sacral ribs abuts against the right ilium. Upwards of thirty caudal vertebræ extend, in nearly a straight line, from the sacrum. The vertebræ at the fore part of the neck have been displaced, and in great part lost. Of the head little is visible, save the mandibular rami. The bones of both fore and hind paddles on the

* Op. cit., vol. ii, plate x, fig. 2.

right side are in an instructive state of preservation, especially those of the hind fin, which exemplifies the slight superiority of length as compared with the fore fin, characteristic of the present species.

The following are admeasurements of corresponding parts of the three skeletons above mentioned, that of "entire length" being now capable of being given by reason of the integrity of the cervical region of the spine between the head and the pectoral or scapulo-coracoid arch.

	Conybeare's specimen. Ft. in. lines.	Buckland's specimen. Ft. in. lines.	Specimen Tab. I. Ft. in. lines.
Entire length (two or three inches of the tail wanting?)	9 5 0	9 8 0	8 9 0
Length of head	0 8 6*	0 8 2	0 8 6†
,, neck	4 0 0	4 10 0‡	4 10 0
,, trunk, from fore part of sternum to end of ischium	3 0 0	3 6 0	2 8 0
,, tail	2 0 0	2 4 0	(imperfect.)
,, pectoral limb	1 10 0	1 9 0	(imperfect.)
,, pelvic limb	2 0 0	2 2 0	(imperfect.)
,, humerus	0 7 0	0 7 6	0 7 6
,, femur	0 7 0	0 7 4	(wanting.)
,, radius	0 3 0	0 3 0	0 3 6
,, tibia	0 3 0	0 3 3	
,, manus	1 0 0	1 0 0§	
,, pes	1 2 0	1 3 0	
Breadth of pubis (transverse diameter)	0 5 0	(obscured)	0 6 0
Length of ischium (longitudinal diameter)	0 4 6	(obscured)	0 5 0

From the amount of concordance in the dimensions of the above three skeletons, it may be inferred that the average length of the mature animal of the present species of *Plesiosaurus* was between nine and ten feet. Two specimens of certain portions of the skeleton, now in the British Museum, one of which is the subject of Tab. III, support this conclusion.

Vertebral characters (Tabs. III and IV).

Cervical series.—The cervical vertebræ of the *Plesiosaurus dolichodeirus*, at the fore part of the neck (Tab. III, fig. 1, *a*, *c* 4—7), have the centrum (*c*) of a length equalling the breadth of the articular end; but the dimension of breadth increases in a greater

* Estimated at that of the lower jaw.

† Nine inches, if the angle of the jaw be restored, as dotted in Tab. II.

‡ It may be that the head has been drawn a little forward in the displacement of the anterior cervical vertebræ.

§ Some of the terminal phalanges are here estimated for.

ratio as the vertebræ enlarge and recede in position; so that the length of the centrum may be one sixth less than the breadth at the middle (Tab. III, figs. 4, 5, 6) and hind part of the neck. There are, however, varieties in this respect, and the equality of length to breadth of centrum is maintained through a greater extent of the neck in some specimens than in others. The vertical diameter of the middle of the terminal articular surface (ib., fig. 6 *c*) is less by nearly one fourth than the breadth of the same. The sides of the centrum are longitudinally concave (ib., fig. 5), as is also the under part (ib., fig. 4), but in a minor degree in the middle and posterior than in the small anterior cervicals (ib., fig. 1, *c*).

The costal surface is at the lower part of the side of the centrum; it is narrow vertically, in proportion to its length in the anterior cervicals, but gains in vertical extent without being elongated in the same degree, and consequently occupies a larger corresponding extent in the middle cervicals (ib., fig. 4, *pl*),* in which the costal surface exceeds one half the length of the centrum; it is divided by a longitudinal cleft, and is situated a little nearer the posterior than the anterior surface of the centrum. In the third to the seventh cervicals (ib., fig. 1, c 7) the costal surface is separated by a tract exceeding its own vertical diameter from the neurapophysial surface (ib., fig. 1, *n*); in the succeeding cervicals the intervening tract equals the costal surface (ib., fig. 4, *c*); and the interval is never less, and is sometimes more, in the cervical vertebræ to near the base of the neck. The terminal articular surface (ib., fig. 6) is moderately convex at its periphery and very gently concave in the rest of its extent, with a small central, often transversely linear, impression in the centre.†

The free surface of the centrum is finely rugose in the smaller anterior cervicals, and is not smooth in any of the others; towards the articular ends the roughness is more marked, by irregular narrow risings and groovings, which become more longitudinal in direction in the succeeding cervicals (ib., figs. 4, 5). The under surface (fig. 5) is concave transversely from the costal pit (*pl*) to the two venous openings, and is convex between those openings, which divide the surface pretty equally into three parts, Lengthwise, as already stated, the under surface is gently concave. The neurapophysial surface is less angular than in some other species, the lower angle being rounded off, making the lower border approach to a curve. Anchylosis of the neural arch with the centrum seems to have been complete in the anterior cervicals of the specimen figured in Tab. III, fig. 1; and I have not yet seen a cervical centrum of the present species from which the neural arch had become detached, save by fracture. The zygapophyses are proportionally large; the anterior ones (ib., *z*, *z*) extend forward, in the anterior vertebræ almost immediately above the centrum, overhanging the

* Here obscured by the confluent base of the rib.

† "The concavity again slightly swelling in a contrasted curve near the middle of the circular area," (Conybeare's first Memoir, p. 582, April, 1821) is the character of the terminal articular surface in the *Plesiosaurus arcuatus*, from the Lias in the neighbourhood of Bristol.

posterior two fifths of the centrum in advance; the articular surface, the length of which equals two thirds that of the length of the centrum, looks obliquely upward and inward; that of the posterior zygapophysis has the reverse aspect. As the cervicals approach the back the zygapophyses diminish in relative size, and their articular surfaces become less horizontal. The posterior zygapophysis (Tab. III, fig. 4, *z'*) overhangs a small part of the end of the succeeding centrum, and the neurapophysis (ib., fig. 4, *n*) rises with a deeper concavity at the back than at the fore part. That this anchylosis had not occurred in the similarly sized and in the larger specimens of the cervical vertebræ of the *Plesiosaurus* described and figured by Conybeare in his first famous Memoir* is due to their having been derived from a younger specimen of a larger species from the Bristol Lias, probably *Plesiosaurus arcuatus*.

The neural spine (Tab. I, *ns*; Tab. III, fig. 4, *ns*) arises narrow between the bases or back part of the prezygapophyses (*z*), and its base extends, increasing in thickness gradually to near the back part of the postzygapophyses (*z'*). The height of the spine averages half the vertical extent of the entire vertebra from its summit to the lower level of the centrum, being rather shorter in the anterior cervicals and exceeding that length at the base of the neck. In the anterior cervicals the contour of the neural spine extends from the fore part of the base, in a curve increasing in convexity at the upper part, and terminating by a rounded apex overhanging, in the foremost vertebræ (as at c 4, Tab. III), the concave contour of the hinder border. The upper part of the spine becomes more squared as the spine itself gains in height, in the larger posterior cervicals, by the increasing fore-and-aft extent of their upper part, as in fig. 4, *ns*.

The pleurapophysis of the axis (Tab. III, fig. 1, *x pl*) has its posterior angle extended backward; that of the third cervical has its anterior angle also produced forward, but in a minor degree. Both angles continue to be more produced in the succeeding vertebræ, but the front one most so, until, in the fifth cervical, they are equal in length; the hinder one then elongates, but they do not touch or overlap the contiguous pleurapophyses until about the tenth cervical vertebra. The extent of this terminally dilated or extended border of the riblet exceeds that of the diameter of the same from its upper articulation outward or downward. The line of articulation is discernible in most of the anterior vertebræ, but in fig. 1 coalescence has commenced, if it be not complete, as in figs. 4, 5, 6, *pl*, in which the expanded part of the pleurapophysis has been broken off, showing the approximated head and tubercle adapted respectively to par- and di-apophysial divisions of the costal surface. In

* "Notice of the discovery of a new fossil animal, forming a link between the Ichthyosaurus and Crocodile, together with general remarks on the osteology of the Ichthyosaurus; from the observations of H. T. de la Beech, Esq. F.R.S., M.G.S., and the Rev. W. D. Conybeare, F.R.S., M.G.S. (Read April 6th, 1821.) Drawn up and communicated by the latter." The observations on the vertebral characters of the new reptile are said to have been made "on the organic remains contained in the Lias in the vicinity of Bristol" (p. 559). 'Transactions of the Geological Society of London,' first series, vol. v.

some vertebræ a low and narrow ridge extends from the neur- to the pleur-apophysial surfaces, as at *c*, fig. 4.

The degree of concavity of the sides of the centrum in the anterior cervicals, exposed in the specimen figured in Tab. III, fig. 1, has been exaggerated by the pressure to which it has been subject, the effects of which are more conspicuous upon the skull: the cancellous mid-part of the centrum has opposed less resistance than the compact articular ends.

The atlas (*a*) has been disarticulated from the occipital condyle (1); the hemispheric articular cup is thus well displayed, with its smooth and shining surface. The coalescence of the centrums of the atlas (*a*) and axis (*x*) is complete. A tubercle from the side of the centrum of the atlas represents the pleurapophysis; its neural arch is broken away; that of the axis developes a spine similar to and but little smaller than that of the third cervical.

The dimensions of the seven vertebræ here preserved in connection with the skull will be seen in Tab. III, fig. 1, where they are figured of the natural size. The average dimensions of a cervical centrum of the present species, from the middle and basal half of the neck, are, as in figs. 4, 5, 6—

	In.	lines.
Length	1	4
Breadth of articular surface	1	6
Height of middle of ditto	1	3
Length of costal pit	0	6
Transverse diameter of outlet of neural canal	0	6

Dorsal series.—The transition from the cervical (Tab. I, C) to the dorsal series (ib., D) is effected by the usual elevation of the costal surface by gradational steps, continued through about five vertebræ, until a single costal surface is presented by a large diapophysis from the neural arch. The number of cervical vertebræ so defined in the specimen figured in Tab. I is forty-one. In the first dorsal, characterised by the diapophysial support of the rib (Tab. IV, figs. 1 and 2, *d*), the non-articular part of the centrum is smoother than in the cervical vertebræ, the ridges or rugæ occupying a smaller extent near the two ends, where they indicate the attachments of the capsular ligaments. The longitudinal concavity between the two ends is uniform and rather more than in the cervicals. The venous foramina are wider apart and not divided by any special transverse convexity on the under surface of the centrum. A vertical ridge leads from the side of the centrum (ib., *c*) to the under part of the diapophysis (ib., *d*), nearer the hind than the fore end of the centrum.

The diapophysis is convex and longest superiorly; the fore part is rather hollowed, the hind part flattened, and both converge to the ridge forming the shorter under surface. The articular surface (*d*) of an irregular oval form, with the small end down-

ward, looks downward, outward, and a little backward, the process being slightly inclined that way. The margin of the articular end of the centrum is better defined than in the neck; about a line's breadth is, as it were, shaved off; the rest of the surface (fig. 2, *c*) is very slightly concave, sometimes undulated, always nearly flat, and with a small central depression, or a tendency there to a tubercle. The length of the dorsal region in the skeleton (Tab. I) 8 feet 9 inches long, is 2 feet 6 inches; the number of dorsal vertebræ is twenty-one.

Sacrum.—Two vertebræ (ib., *s*) succeeding the dorsals are distinguishable, through the greater thickness and straightness of their short pleurapophyses, as sacral; these elements abut against, or afford ligamentous union to, the iliac bones.

Caudal series.—The caudal vertebræ (Tab. I, c *d*, Tab. IV, figs. 3—9) are shorter in proportion to their breadth than the others; the centrum approaches to a cubical figure, the under surface (figs. 4 and 7) becoming broad and flattened; and the contour of the terminal articular surfaces shows a similar tendency to flattening, giving a transversely extended quadrate figure, with the angles rounded off (figs. 5 and 8); the margin is thicker, more rounded off, less defined than in the dorsal vertebræ. The articular surface itself is more concave than in the antecedent regions of the backbone, and becomes deeper in the terminal subcompressed vertebræ (fig. 9); the movements of the tail in swimming having been helped here by a greater amount of yielding intervertebral substance, approaching in the same degree to the condition of the spine in fishes. The costal surface (figs. 3, 6, *pl*) is elliptic, with the long axis subvertical, the margin prominent, the cavity simple and rough for the ligamentous attachment of the riblet; it is situated on the upper half of the centrum close to the neurapophysis, the outer end of the base of which contributes to the upper part of the margin in the anterior caudals (fig. 5, *d*).

The pleurapophyses in this region (Tab. IV, 5, *pl*) do not expand terminally, as in the neck; they are short, thick, and straight, simulating transverse processes; their non-confluence with the centrum exemplifies the minor vigour of vital co-ossifying influences in terminal parts.

The hæmapophysial surfaces (fig. 3 *h'*) impress the inferior angles of the posterior surface of the centrum; occasionally, where a hæmapophysis has become anchylosed and broken off, its adherent base gives the appearance of a process from that part of the centrum (ib., figs. 6, 7, 8, *h'*). The venous foramina are at the lower part of the sides of the centrum. The neural arch (figs. 3, 5, *n*) rapidly diminishes in size and in the length of the neural spine, *ns*. The zygapophysial surfaces become more vertical, the anterior, *z*, looking inward; the posterior zygapophyses, *z'*, are the first to disappear. The hæmapophyses (fig. 5, *h*) are free, and were ligamentously connected with the centrum above and with each other below, circumscribing there the hæmal canal. The proximal surface is expanded, with a subtriangular facet cut obliquely at the anterior part for articulation with its own surface, and with a smaller, less definite

surface posteriorly for the intervertebral substance and a small part of the succeeding centrum, where a slight expansion of the everted border of the articular surface is the sole indication of such hæmapophysial junction. In the terminal vertebræ these surfaces with the hæmapophyses have disappeared, and the centrum, now showing a compressed form, supports only a contracted, anchylosed, seemingly exogenous neural arch, which finally disappears.

The following are transverse diameters of the centrum in different regions of the spine, in the specimen, 8 feet 9 inches long, of *Plesiosaurus dolichodeirus*, figured in Tab. I:

	In.	lines.
Tenth cervical vertebra	1	0
Middle dorsal ditto	2	0
Tenth caudal ditto	1	3

Cranial characters (Tabs. II and III).

The skull in this skeleton presents, what is rare, the side or profile view (Tab. II) like that of the succeeding anterior cervicals. Its upper part is much injured. The following bones are recognisable:—mastoid 8, tympanic 28, squamosal 27, malar 26, maxillary 21, premaxillary 22; the end of the long pterygoid is seen at 24, abutting against the lower end of the tympanic. But little of the composition of the mandible is discernible: the tightly closed jaws show the extent of the interlocking of the long, slender, curved, and sharp-pointed teeth.

Of those of the lower jaw the crowns of upwards of twenty may be traced; the longest occupying the middle three fourths of the series, and the largest of these being the foremost. In some parts of the series two teeth pass into the same dental interspace of the opposite jaw.

The admirably wrought-out specimen figured in Tab. III, fig. 1, exhibits the upper surface of the somewhat crushed skull. Of the basi-occipital a part of the upper surface (1) and of the single median convex condyle is shown. The exoccipitals (ib., 2) preserve their connection with the lateral and upper parts of the basi-occipital, and show the surfaces—seemingly sutural—from which the superoccipital (ib., 3) has been displaced. These surfaces (2, 2) are thick and triangular; they are parallel with the middle of the foramen magnum, the lower half of which is formed by the basi- and ex-occipitals. From the outer and back part of the exoccipital the paroccipital process (4, 4) is continued; of subtriedral form, long, slender, and tapering to a thin rounded apex: the outer side appears to be sutural, and that of the left side is applied to the tympanic (ib., 28): the length of this process is 8 lines. The breadth of the occiput, outside of the exoccipitals, is 1 inch 5 lines; that of the foramen magnum is 6 lines. That the rough triangular upper surfaces of the exoccipitals are natural, not the result of frac-

ture, I infer from their being on the same level, and from the corresponding surfaces being presented by the single arched bone (3) representing the superoccipital. This has been displaced by the pressure operating not quite vertically, but with an inclination from the left to the right, which has turned the spines of the cervical vertebræ to the right, and which has so far displaced the superoccipital in the same direction that it lies with its concavity or arch embracing, as it were, the right superoccipital, this concavity having formed the upper half of the foramen magnum. The apex of the superoccipital lies beneath the right branch of the parietal; the outer surface of the piers of the superoccipital arch is moderately smooth and convex; the breadth of the base of the arch is 1 inch 3 lines, that of the span of the arch is 5 lines.

The parietal (ib., 7) is thick and transversely extended posteriorly, where it is overlapped by the mastoids (8), anterior to which it contracts to form the crest between the temporal fossæ. The crest is interrupted by the parietal foramen (*f*), anterior to which it is resumed for a short extent—3 lines, before the frontal suture. The total length of the parietal is 1 inch 11 lines; the length of the crest is 1 inch 3 lines. The thick and rather rugged hinder bifurcate part of the parietal is overlapped or embraced by the mastoid (8), and these bones curve outward and backward to articulate with the squamosal (27) and with the tympanic (28), which is continued in the same direction to the joint of the mandible (29). All these bones together form a strong arch, curved backward in the present specimen, but owing its horizontal position to the posthumous pressure, and having the piers of the arch directed downward as well as outward and backward in the natural state.

The suture between the frontals (11) remains, and that between the postfrontals (12) and the expansions of the parietal (7′) upon the sides of the cranium may be traced. There is a smooth superorbital (11′) between the rougher frontal and the orbit, unless the fissure defining them be a fracture and not a suture. The external facial plate of the prefrontals is rough; it overlaps the fore part of the frontal and part of the nasal, and extends to the small external nostril. The nasals (15) overlap the fore part of the frontals, and extend about as far in advance of the nostrils as they do behind them, continuing the median ridge from the frontals forward, in which, however, the median suture is visible. The outer surface of the maxillaries and premaxillaries shows a kind of granular rugosity, which subsides in the maxillary as this bone (21) extends beneath the orbit. The limits of the lacrymal (73) are not definable. The malar (26) forms the hinder half of the suborbital boundary; its surface is smooth, and increases in breadth to beyond the orbit, when it contracts and becomes rugous where it joins the postfrontal (12) and squamosal (27). The bony boundary between the orbital and temporal cavities is crushed and much cracked: but the outer end of a postfrontal or postorbital is wedged into the squamous union of the malar and squamosal. The latter (27), of a tri-radiate form, curves from the malar round the outer and back angle of the temporal fossa, and extends backward upon the tympanic: the ray directed

mesiad, and overlapping the mastoid (8) and tympanic (28), is the longest, and terminates in a point: the surface of the bone is smooth.

The temporal fossæ are broader than they are long. At their forepart the parietal side-wall of the cranium expands as it advances, and is continued into the postfrontal or postorbital partition.

The orbits are rounded anteriorly, and both the upper and under parts of the frame make an angular junction with the straight hinder part.

The nostrils have the usual small size and backward position.

In both orbits some of the thin sclerotic plates of the eyeball (*s*, *s*) are preserved; this is the first specimen in which I have had evidence of this structure.

The interlocking of the teeth of the upper and lower jaws, through the singular care and skill devoted by Mr. Harrison to the removal of the matrix, is peculiarly well displayed in this instructive fossil.

The foremost tooth in each premaxillary make a pair, which curve forward and downward between the two foremost teeth of the lower jaw, the premaxillary teeth slightly diverging as they descend, Tab. III, fig. 3. The succeeding premaxillary teeth, four in number, alternate with mandibular ones. I cannot make out with certainty the maxillo-premaxillary suture, but the fifth tooth, counting backward, seems to be near to or upon it. The second premaxillary tooth is double the size of the first; the third, fourth, and fifth gradually diminish; the sixth (first maxillary ?) is small; the seventh tooth suddenly resumes the size of the second; and the eighth, of nearly equal size, curves down close to the seventh, and the two are interposed between the interspace of opposite mandibular teeth. From four to five smaller teeth are traceable behind the eighth, and there may have been more in the upper jaw.

Of the lower jaw ten teeth are shown on each side; the second, third, fourth, and fifth are the longest and largest, as in Tab. II. In general, the teeth of the upper jaw are separated by intervals allowing the passage of those of the lower; the teeth of the foremost premaxillary pair being closer together; and those of the foremost mandibular pair being wider apart. They all present the usual generic character of crown—long, slender, curved, pointed, circular in transverse section, with the enamel finely but definitely ridged longitudinally. The longest exserted crown measures ten lines, the shortest four lines, the thickness being in proportion.

The true number of the teeth in the lower jaw is yielded by the specimen of the dentary bone, Tab. III, fig. 2, in which twenty-five alveoli are shown on one side, and twenty-four on the other. The size of the alveoli, and the extent of their interspaces, are greatest at the anterior half of dentary. The small successional teeth at the posterior part of the series are so advanced as to look like a double row at that part. A longitudinal groove or depression at the inner side of the base of the alveoli lodged the thicker mass of the vascular gum overlying the matrices of the successional teeth.

The skull of the *Plesiosaurus dolichodeirus* is broad in proportion to its length, with

a broad and short muzzle, of an equilateral triangular figure if the transverse lines across the fore part of the orbits be taken as the base, the two sides converging to the rounded apex in almost straight lines, with a feeble indication of a constriction where the maxillo-premaxillary suture seems to be. The contour is undulated by the expansions for the sockets of the larger teeth, which produce risings, with intervening furrows on the granulate alveolar borders of the jaws. The mandibular rami converge to their terminations at the symphysis, which is not prolonged or expanded.

The specimen (Tab. III, fig. 1) from the Lias of Charmouth was wrought out of its matrix by the estimable discoverer of the Liassic Dinosaur (*Scelidosaurus*) described in a former Monograph. It is an admirable example of patience, pains, and skill; in the bestowal of which, for the furtherance of science, upon the fossils roughly wrought out of the quarries in his neighbourhood, Mr. Harrison found solace during the long and trying illness which confined him to his bed, until his final release by death.

Pectoral and pelvic limbs (Tab. I, figs. 2, 3).

To complete the characters of *Plesiosaurus dolichodeirus* I have reproduced, in outline, the bones of the pectoral, fig. 2, and pelvic, fig. 3, limbs, as they are preserved in the type-specimen. The humerus, 53, shows rather more convexity at the anterior border, and a deeper concavity at the posterior border than in some other species (*Plesiosaurus Hawkinsii*, *Pl. macrocephalus*,* *Pl. rugosus*, e. g.). The radius, 54, and ulna, 55, are of equal length; the ulna not being shorter than the radius, as in *Pl. Hawkinsii* (Tab. XIV, fig. 6); the ulna has not the olecranal process or epiphysis, as in the *Pl. rugosus* (Tab. XIV, fig. 2, 55′); and both antibrachial bones are less broad, in proportion to their length, than in the *Pl. macrocephalus* † (Tab. XIV, fig. 4). The carpus shows seven bones, four in the proximal, three in the distal row; their homologies will be pointed out in the description of *Plesiosaurus rugosus*. The metacarpal of the first digit (Tab. I, fig. 2, 1), answering to "pollex," supports at least three phalanges; that of the fifth digit, seven phalanges; the metacarpal of each of the others, six phalanges, but the terminal ones may be wanting in some. The pelvic fin (fig. 3) is rather longer than the pectoral one; in both fins the fifth digit (v) articulates on a more proximal plane than the others, *i. e.* nearer the trunk, as in most other *Plesiosauri*. In the same skeleton the pectoral limb equals seventeen of the middle cervical vertebræ in length;‡ in *Pl. macrocephalus* it equals sixteen of these vertebræ, in *Pl. rugosus* it equals fifteen.

* 'Geological Transactions,' 2nd series, vol. v, pl. 43.

† Ib.

‡ The artist has drawn the outline of the limb-bones, figs. 2 and 3, on a larger scale than that of the skeleton, in Tab. I.

Plesiosaurus homalospondylus (Tabs. V—VIII).

In the year 1842 I examined, in the Museum at Whitby, Yorkshire, a collection of Plesiosaurian vertebræ, which had been taken out of a heap of rubbish from the old alum works carried on in the upper Alum Shale—a part of the Liassic series on that coast, characterised by the *Ammonites heterophyllus*, Sow.

The vertebræ were divisible into two groups, indicative of two species of *Plesiosaurus*.

Of one kind there was a series of sixteen consecutive cervical vertebræ, characterised by the unusual concavity of the terminal articular surfaces of the centrum. On making a section of two of these vertebræ cemented by the matrix in their natural state of co-adaptation, the margins of the opposed articular surfaces were two lines apart, showing the thickness of the inter-articular connecting ligamentous substance at that part, while the middle of the articular surfaces left an interval of eleven lines, thus approaching the ichthyosaurian type of vertebral union.

The following were dimensions of the centrum of these cervicals.

	In.	lines.
Length	1	9
Breadth of articular surfaces	1	11
Height of ditto	1	10

The inferior surface of the centrum showed a median longitudinal convex ridge between the two wide elliptical venous foramina. I named the species indicated by these vertebræ *Plesiosaurus cœlospondylus*,* in reference to the hollow terminal articular surfaces. I hope to have, at a future opportunity, further means of illustrating this species.

The second series of vertebræ presented almost flat articular surfaces of the centrum (Tab. V, figs. 3 and 6); the inferior surface was devoid of a median ridge, or had only a slight rising (fig. 4, *v*) between the venous foramina, which were smaller and more narrowly elliptical (ib., figs. 4 and 7) than in *Pl. cœlospondylus*; the middle of the surface was bounded laterally by the costal surfaces (ib., *pl*), and was nearly flattened, being very slightly concave, both lengthwise and transversely. The costal surface is of a narrow elliptical form, with the long axis parallel with that of the centrum; the dividing line or fissure is not conspicuous; it is situated, as usual, rather nearer the back than the front end of the centrum (Tab. V, fig. 2, *pl*); and a space more than twice its vertical diameter intervenes between it and the neurapophysis (ib., *np*), or

* Κοῖλος, hollow, σπόνδυλος, vertebra.

neurapophysial surface. A low, longitudinal rising, or obtuse ridge, traverses the free surface of the side of the centrum midway between the pleur- and neur-apophysial articular surfaces.

The following were dimensions of the centrum of a cervical vertebræ answering, or nearly so, in position, to that of the *Plesiosaurus cœlospondylus* selected for measurement—

	In.	lines.
Length	2	0
Breadth of the articular surface	1	10
Height of ditto	1	6

These dimensions showed the greater proportional length of the cervicals of the present species; and, concurring with the more obvious difference in this shape of the terminal articular surfaces, I thereupon devised the name of *Plesiosaurus homalospondylus*,* indicative of the even or level character of those surfaces, for the species so characterised.

I have subsequently received several additional vertebral evidences of both these species of the Upper Lias, or Alum Shale of Whitby, and, finally, have had the opportunity of studying two almost entire skeletons of the *Plesiosaurus homalospondylus* from that locality, one of which (Tab. VIII) is now in the Museum of the Philosophical Society of York, and the other (Tab. V) has been purchased by the Trustees of the British Museum, where it is now exhibited in the Geological Department. Both of these specimens exhibit the striking character of the genus PLESIOSAURUS in a maximised degree, viz., in the length of the neck and the smallness of the head.

I propose, first, to describe the specimen in the British Museum, Tab. V.

This specimen gives indications of the same conditions of interment in its matrix, and of the operation of subsequent gradual pressure, as that of the species last described, from the lias of another part of the kingdom.

It has sunk into the mud, which afterwards became petrified, either prone or supine; for I have been unable to obtain evidence as to whether the present exposed part of the skeleton was wrought out from the upper or under surface of the block, as removed from the quarry; but we may assume the former, and consider that the animal was originally imbedded with the upper or dorsal surface toward the observer. Both fore and hind paddles were outstretched at right angles with the axis of the trunk, but only their proximal bones or segments have been preserved. The skull and cervical vertebræ have maintained their original position. At the base of the neck, where the neural spines, from their height and breadth, began to afford a surface upon which the dislocating force could operate, they have begun to yield toward the left

* Ὁμαλός, planus; σπόνδυλος, vertebra.

side, and, in the dorsal region, D 1 — 60, are turned flat in that direction. At the base of the tail, where these flattened surfaces again become diminished in extent, the vertebræ gradually resume their vertical or prone position, the summits of the spines being uppermost, as far as the seventieth (counting from the head), beyond which some dozen of the terminal caudals are jumbled together in an irregular group, as if that part of the carcass, supporting perhaps a caudal expanse of integument or fin, had been subject to some disturbing influence prior to complete imbedding in the matrix.

I conclude that this partial rotation of the dorsal series took place before the petrifaction of the bones and bed; because the ribs of the right side have slipped from their attachments to the diapophyses, in a degree corresponding with the extent of the rotation. For, had they been cemented in their natural connections by the Lias stone, *i. e.*, after the petrifaction of the mud, and prior to the operation of the extraneous pressure, they might have been expected to have been bent or broken, when pressed into the same plane with the neural spines, without any slipping from their previous joints; whereas this dislocation implies a rotting away of the articular ligaments, and a certain yielding of the surrounding bed.

The chief characteristics of the skeleton of the *Plesiosaurus homalospondylus* are, the length of the neck, the height and breadth of the dorsal and contiguous cervical and caudal spines, with the smallness of the head. The length of the neck is due both to the number of vertebræ—thirty-eight, and to their proportionate length individually, and chiefly to the latter character, as compared with *Plesiosaurus dolichodeirus* (Tab. I).

I caused to be carefully removed from the matrix of the present skeleton the thirteenth and fourteenth (Tab. V, figs. 2—4) of these instructive vertebræ, the length of the centrum in which agreed with that on which I had made notes and drawings in 1842. They corresponded in every other particular with these vertebræ. The low, longitudinal ridge or rising (Tab. V, figs. 2, 5, *r*) on the side of the centrum may be traced throughout the neck. Fig. 7, Tab. V, gives a view of the under surface of the eighth cervical vertebra; fig. 6 gives an end view, and fig. 5 a side view of the centrum of the third cervical vertebra, all of the natural size. The specific characters are well exemplified in these, which may be profitably compared with the figures of the corresponding vertebræ of the *Plesiosaurus planus*, in a former Monograph,* as exemplifying the degree in which vertebral characters are developed in the different species of the genus.

The cervical ribs, as indicated by the articular surface (Tab. V, figs. 2, 7, *pl*), are of small size in proportion to the rest of the vertebra, until about the thirtieth, in which the transverse outstanding part of the stem is two inches three lines in length, and the longitudinal part two inches six lines. In the thirty-fourth vertebra this has attained

* Volume of the Palæontographical Society for 1862, issued in 1864. 'Supplement No. II to the Monograph of the Fossil Reptilia of the Cretaceous Formations' (Tab. I, figs. 20, 22, 25).

a length of four inches; the production, anterior to the transverse stem, being nearly an inch in length. In the thirty-fifth vertebra (Tab. VII, C 35) the costal surface projects, the rib begins to ascend, the anterior production to shorten, the posterior one to lengthen. In the thirty-seventh (ib., 37) the rib is supported in equal proportions by the centrum and by a diapophysial growth of the neurapophysis. In the thirty-eighth (C, 38) the rib has passed almost wholly upon the diapophysis, and has assumed a simple rib-like character, slightly bent, with a length of six inches. In the thirty-ninth vertebra (ib., D 1) the transit from centrum to neurapophysis, *np*, is complete, denoting the first of the dorsal series. In the second dorsal vertebra of the present skeleton the rib has slipped forward from its joint, *d*. In the forty-third (Tab. V, fig. 1) it is depressed an inch below the diapophysis. In the forty-sixth to the fiftieth vertebræ the heads of the ribs lie beneath the centrums, and the side view of the whole of those vertebræ is obtained. In the succeeding dorsals the ribs gradually approximate their suspending processes, and have resumed their articulation at the twentieth dorsal, or the fifty-eighth vertebra, counting from the atlas.

The ribs of the forty-seventh to the fifty-first vertebræ are from sixteen to seventeen inches in length; they are the longest of the series. The articular head presents a diameter of one inch and a half; the anterior surface is convex transversely; the outer part of the posterior surface is rather concave in the same direction, so that the outer margin of the proximal half of the rib, to near its head, presents the character of an obtuse rim or ridge. They gradually decrease in size as the vertebræ recede in position from the fiftieth; and, at the sixtieth, are reduced to a length of four inches: this and the two succeeding ribs seem to have become anchylosed to the diapophyses. In the sixty-second vertebræ the rib suddenly augments in thickness, extends its articulation downward upon the centrum, and represents a sacral vertebra (Tab. I, s). That of the sixty-first vertebra is somewhat less thick, but it may have assisted in affording attachments to the ilium (ib., 62), the proximal end of which bone is in contiguity with the converging terminations of the ribs of the sixty-first and sixty-second vertebræ. The anchylosed condition, with shortening of the caudal ribs, or pleurapophyses, give them the usual character of transverse processes in the caudal region.

The neural spines, thin and antero-posteriorly extended in the neck (Tab. V, fig. 2, *a*, 2, *ns*), have been more or less broken away, in the operation of exposing the specimen, from the anterior three fourths of the vertebræ in that region. Their height gradually decreased as they approached the head and receded from that of the thirtieth vertebra (ib., 30), which rises four inches from the summit to the neural arch, having a fore-and-aft diameter of two inches three lines, and a thickness of three lines. The former diameter is least a little above the origin of the spine, and gradually increases toward the summit, where the spines are in contact. In the thirty-third vertebra the neural spine is five inches in length, and its breadth of two inches three

lines is maintained through nearly the whole of that length, in corresponding close contact with the contiguous spines. In the thirty-seventh vertebra (Tab. VII, 37) the length of the neural spine is five and a half inches; it has a little increased in thickness; the fore-and-aft diameter continues the same. In the second dorsal the neural spine is six inches four lines in length, with a thickness of six lines. These dimensions are continued to the fifty-eighth vertebra, save that, in the posterior half of the dorsal series, the spines have less fore-and-aft breadth at their proximal third, and leave correspondingly wider intervals; they are in contact at their more expanded distal portions. From the fifty-eighth vertebra they gradually decrease in length to the sixty-second, or sacral vertebra, showing a height of less than four inches, with a terminal fore-and-aft extent of two inches, and a thickness of six lines. They decrease in all dimensions as the caudals recede from the trunk, and most so in fore-and-aft extent, leaving wider interspaces; by which character, with the higher position on the centrum, and anchylosed condition of the pleurapophyses, a caudal vertebra may be distinguished from a cervical of similar size. The caudal centrums are also thicker in proportion to their length, and the under surface, if exposed, would doubtless also yield the character of the hæmapophysial pits.

The dorsal diapophyses progressively increase from the first (Tab. VII, D 1, 2, *d*), and attain, at the fifth dorsal vertebra (Tab. V, fig. 1), a length of two inches three lines along the upper border. The rib-surface is cut from above downward and inward, shortening the under extent of the process. A low ridge is continued from the posterior angle of the neurapophysis upon the back part of the diapophysis, which expands to the truncate articular surface. After the sixteenth dorsal the diapophyses gradually shorten to the sacral vertebræ, where they have almost subsided.

The zygapophyses in the neck (Tab. V, fig. 2, *z*, *z'*) and greater part of the back are nearly horizontal, the anterior ones looking a little inward as well as upward, the posterior ones the reverse; they are given off nearer the base of the neurapophysis than usual (compare Tab. V, fig. 2, *z*, *z'* with Tab. III, fig. 4, *Plesiosaurus dolichodeirus*, with Tab. X, fig. 1, *Pl. rostratus*, and Tab. IV, fig. 11, *z*, *z'*, 'Monogr.,' 1862, *Pl. Bernardi*); towards the end of the back their aspect gradually changes; and, in the tail, the articular surface becomes almost vertical; that of the anterior ones, which are most developed and longest retained in the vertebral series, looking inward. The terminal articular surfaces of the centrum of the last dislocated caudal vertebræ are, as usual, more concave than in the neck.

The development of the neural spines throughout the trunk and base of the neck is such as to impede inflection in the vertical direction. At the anterior half of the long and slender neck this bend would, indeed, take place in some degree; but the greatest flexibility would be from side to side. The provision for the attachment of the vertebral muscles in the trunk is very great, indicative of corresponding power of regulating the movements and position of the body during the application of the

lengthened, slender neck, and small head, in the capture of fishes or other active marine prey.

The whole framework of the trunk is singularly massive, and the character of this part of the skeleton, as shown in the specimen (Tab. V), is especially striking in contrast with the slender neck and small head of the animal.

Of the Skull (Tab. VI).

The skull (Tab. VI), from the occiput to the end of the snout, is 9 inches long; it measures 4 inches 4 lines across the middle of the temporal depressions, 3 inches 6 lines across the occiput, which rises but 1 inch in height above the foramen magnum; the intertemporal part, or parieto-frontal crest, rises into a sharp ridge; the length of the temporal fossa is 2 inches 9 lines, the breadth is 2 inches. The diameter of the orbit is 1 inch 6 lines; from the fore-part of the orbit to that of the snout is 4 inches. The elliptical nostril shows a long diameter of about 6 lines, it is situated about 8 lines in advance of the orbit, and about the same distance from its fellow. The inter-narial portions of the nasal and premaxillary bones rise into an obtuse ridge. The teeth are small, slender, slightly recurved at the fore-part of the jaw, where the enamelled crown of the longest does not exceed 10 lines. No sutural evidence of cranial structure is discernible; the bones about and between the orbits show the effects of pressure. Estimating the length of the skull by that of the lower jaw, about two inches should be added to that taken from its exposed and visible part.

This part of the skull (Tab. V) is susceptible of satisfactory comparison with the corresponding region of the skull in the *Plesiosaurus dolichodeirus* (Tab. III, fig. 1), the species which most resembles the *Plesiosaurus homalospondylus* in the length of the neck and the small proportional size of the head.

By comparing Tab. III with Tab. VI, in which the skulls of the two species are figured of the natural size, from probably mature individuals of average size, and from the same aspect, the difference of proportion and form is such, and so obvious, that, were two skulls of existing lizards to be so contrasted, it is probable that some Erpetologists would be led to sever them more widely than by specific bounds. The composition of the cranium, the position and relative size of its principal cavities, and especially of the nostrils, the character of the dentition, are, however, so strictly Plesiosaurian in the two fossil skulls here compared, that there is no sufficient ground for encumbering the Sauropterygian group with one or two additional generic names.

The skull of *Plesiosaurus homalospondylus* is longer in proportion to its breadth, more oblong in shape, more obtusely terminated anteriorly. It is possible that the skull of the *Plesiosaurus dolichodeirus* compared (Tab. III) may have suffered more horizontal pressure, but not such as to have affected its triangular shape due to the

more rapid convergence of the sides of the upper jaw to the more pointed muzzle. The temporal fossæ may appear broader than natural in this crushed skull, but with due allowance this shape was square, not oblong, as in *Plesiosaurus homalospondylus*. The intervening parieto-frontal crest is relatively longer, and we may infer that the biting muscles were larger and more powerful in relation to the more massive proportions of the dentigerous parts of the jaws in *Plesiosaurus homalospondylus:* the orbits are relatively less; their antero-posterior diameter is less than one fifth of the same diameter of the skull taken from the back part of the parietal (7) in *Pl. homalospondylus;* it is more than one fifth in *Pl. dolichodeirus;* the orbits are equidistant from the two extremes of this diameter in *Pl. homalospondylus;* they are nearer the back part of the head in *Pl. dolichodeirus*. In *Pl. rostratus* (Tab. IX) the temporal fossæ present somewhat intermediate proportions between those in the two foregoing species; but the rostral production of the maxillary part of the skull sufficiently distinguishes the cranium of *Pl. rostratus* from that of previously known species in a comparison of detached skulls; whilst its greater relative size to the body more especially distinguishes it from that in *Pl. homalospondylus* or *Pl. dolichodeirus*.

In *Pl. Hawkinsii** the longitudinal diameter of the temporal fossa exceeds the transverse diameter, but not in so great a degree as *Pl. homalospondylus*, and the upper jaw is relatively narrower than in that species. This is also the case in *Pl. macrocephalus*,† in which there is a more marked constriction of that part, anterior to the orbits, showing a tendency to the "rostral" character, which is exaggerated in *Pl. rostratus*.

Pectoral and pelvic arches and limbs (Tabs. V and VIII).

Of the limbs only the humeri and femora have been preserved in the skeleton (Tab. V); these bones show the usual form, with their respective characteristic modifications, as exemplified in the different contour of the anterior border, which is straight or partly convex in the humerus, and is concave in the femur. The length of the humerus is 12 inches, that of the femur 13 inches; the distal breadth is nearly the same in both, namely, 6 inches. In the right femur, the coarse fibrous texture which pervades the whole thickness of the bone is exposed. A portion of the extensive scapulo-coracoid arch comes into view from beneath the anterior dorsals on the right side (Tab. V, 52). The ilium (ib., 62) presents the usual form; straight, slender at its proximate end, with a slightly twisted, subcylindrical shaft, expanding to a breadth of nearly three inches at its acetabular end. The entire length of the

* 'Geol. Trans.,' 2nd series, vol. v, pl. 45.

† Ibid.

skeleton (Tab. V) is fourteen feet, which would be increased by several inches were the tail entire and outstretched.

The specimen of *Pl. homalospondylus* in the Museum of the Yorkshire Philosophical Society is larger than the one in the British Museum, but has been lithographed on a smaller scale in Tab. VIII; it measures 16 feet 6 inches in total length. It lies in a somewhat similar posture to that in the British Museum, but with the long and slender neck and anterior dorsals bent so as to give a concavity to the dorsal contour of the animal; the caudal vertebræ, which are better preserved, are also bent in the same direction, and all the vertebræ follow in their consecutive undisturbed juxta-position in both skeletons. The numbers of the vertebræ in the cervical and dorsal series respectively appear to be the same. The diapophysis has got entire possession of the rib at the fortieth vertebra, counting from the head; and the costal surface begins, with its process, to sink again upon the centrum, at the sixty-seventh vertebra, which the thickness of the diapophysis indicates to be a sacral vertebra. Beyond this may be counted twenty-seven caudal vertebræ, and it is not probable that their number exceeded thirty.

The cervical vertebræ show the same distinctive characters of the species which have been already defined; the neural spine is preserved in a much greater proportion of the cervical series; in the fifteenth cervical it shows a height of two inches, and a nearly equal antero-posterior breadth; with a broadly truncate summit, having the angles rounded off. The vertebræ keep their proportion of length from this point to the end of the dorsal series; they then grow shorter to the end of the tail, throughout the greater part of which the centrum is deeper, and the neural spines longer and narrower, than in the neck, indicative of the greater mass of muscle operating on the tail, and also its greater flexibility in a given extent. The costal series has suffered much more displacement and loss in the York specimen than that in the British Museum; the larger ribs are a good deal jumbled and broken in the region of the trunk or thoracic abdominal cavity, but they show the same massive character. The ischio-pubic part of the pelvis has been drawn away, at an acute angle, from the ilium and sacrum; its inner or upper surface is exposed at 63, 64, Tab. VIII. The right pelvic limb has been moved forward, with the head of the femur lying upon the lower end of the right coracoid. The right pectoral limb extends forward from near its normal place of articulation with the coracoid; but it has been turned bodily over, showing its inner or palmar surface. The limbs of the left side are huddled in a dislocated and incomplete state beneath the hinder part of the trunk.

The presence of both these limbs, in an excellent state of preservation, supplies the chief deficiency in the specimen in the British Museum previously described.

The pectoral limb, as in *Pl. dolichodeirus*, is rather shorter than the pelvic one; its entire length is 3 feet 8 inches, equalling sixteen vertebræ towards the base of the neck. The humerus, 13 inches in length and $7\frac{1}{2}$ inches in distal breadth, is broader

there, in proportion to its length, than in the *Pl. dolichodeirus* or than in the *Pl. rostratus;* its anterior margin, as in the skelcton Tab. V, is more straight than in those species. The antibrachial bones (54, 55) show intermediate proportions of length and breadth between those in *Pl. dolichodeirus* (Tab. I, fig. 2) and *Pl. rostratus* (Tab. IX). They present the usual characteristics of radius (54) and ulna (55) in the present genus, and they are of equal length. The hand measures two feet in length, and is somewhat longer in proportion to the arm and forearm than in the two above-cited species; it also shows rather more breadth. The carpus consists of six bones, three in each row, and with less inequality of size. The distal bones occupy an equal breadth with those of the proximal row, and do not allow the base of the fifth metacarpal to extend backward to the proximal row, as in thc species of which the carpus is figured in Tab. XIV. The bases of the five metacarpals (in Tab. VIII, 57) are on the same transverse line; and if this specimen should truly exhibit the relative position of the bones of the pectoral fin, characteristic of the species, it adds a well-marked distinction of the *Pl. homalospondylus.* The first, or radial, or innermost metacarpal (57), supports a short digit of three phalanges; the second a digit of seven phalanges; the third the same; the fourth has a digit of six phalanges; the fifth is obviously imperfect.

The pelvic limb (Tab. VIII, 65, 69) is 3 feet 9 inches in length; the femur (65) is 14 inches long and $7\frac{1}{2}$ inches across the distal end. The tibia and fibula are respectively longer than their homotypes the radius and ulna; the foot is 2 feet in length and $7\frac{1}{2}$ inches in basal breadth. The tarsal bones are similar in number and arrangement to those of the carpus; and as the bases of the five metatarsals (69) are in this limb also on the same transverse line, I have the greater confidence in the natural structure being here shown in both limbs, and that they thus exhibit a distinctive character, of specific value, from the other Plesiosauri described in the present Monograph.

Plesiosaurus rostratus, *Owen.* Tabs. IX—XIII.

The specimen on which this species is founded was obtained, in 1863, by Edward C. Hartsinck Day, Esq., F.G.S., from the Lower Lias at Charmouth, Dorsetshire, by whom it was transmitted to London for inspection, and it has been purchased by the Trustees of the British Museum, where it is now exposed in thc gallery of Geology. It is figured, one ninth of the natural size, in Tab. IX.

This skeleton, like most of the plesiosaurian ones that have come under my observation, indicates the ordinary and tranquil character of the death and burial of the individual; it has sunk entire, relaxed, and prone, with outstretched limbs, in its matrix, when this was soft and yielding; and, as decomposition loosened the liga-

mentous attachments of the vertebræ and of their elements, they have yielded to external pressure or movement of the matrix, and have rotated on their axis—some of the long-spined vertebræ to the right, some to the left—with a slight displacement of the longer ribs from their attachments.

The third cervical vertebra is displaced about three inches below the axis and atlas, which remain in connection with the occipital tubercles, the third to the fifteenth cervicals are prone with the spines uppermost, and the pleurapophyses in natural connection with the sides of the centrum, the lower part of which is buried in the matrix. Except a slight dislocation between the seventh and eighth, these cervicals have retained their natural sequence and relative position. As the spines grew longer and larger they offered a surface upon which the superincumbent pressure could operate, so as to rotate the vertebræ sideways; and from the sixteenth to the twenty-eighth inclusive, they are turned half round, with the spines downward or to the left; but all these vertebræ retain their natural mutual connections. The twenty-ninth vertebra is dislocated, exposing the anterior articular surface of the centrum; the thirtieth has suffered fracture of its spine; the thirty-first and thirty-second are partly bent to the left; the thirty-third and thirty-fourth are turned with the spines to the right side; that of the thirty-fifth is broken from its neural arch; the thirty-sixth to the forty-eighth vertebræ have the neural spines turned to the right, retaining almost their natural relative positions. The forty-ninth vertebra has kept the original prone position, as when imbedded; the next ten show the side view, with the neural spines to the right; the sixty-first to the sixty-fifth are prone, but with a slight deviation of the neural spines, some to the right, some to the left; the next six vertebræ have yielded in the opposite direction; there is then a deeper space, equal to the extent of five vertebræ, in which there are the centrums of three vertebræ and some hæmapophyses irregularly scattered. Beyond this part the terminal caudal vertebræ resume their position and natural connections, and are preserved, seven in number, to the last. The antecedent exceptional violence shown in the caudal series has probably been due to the tugging and gnawing of some predatory animal, whilst this part of the dead and partly decomposed Plesiosaur continued to be exposed at the sea-bottom.

The scapulæ (51) and articular ends of the coracoids (52) appear parallel with the twenty-fifth to the twenty-seventh vertebræ, the left being rather further back than the right. Both humeri (53) have been dislocated at the shoulder-joint by superincumbent pressure, and the articular ends of the scapulæ overlap their heads. The rest of the bones of the pectoral fins have retained their natural relative position, protected by the tough, closely-fitting dermal sheath, until this slowly dissolved away. The iliac bones (62) lie by the sides of the forty-seventh to the fiftieth vertebræ, almost in the axis of the spine, with their proximal ends turned backward, and their acetabular end forward, having become detached from the thick, converging pleura-

pophyses of the forty-scventh and forty-eighth vertebræ (s, s) which overlie the ischium (63) on the left side of the body. The articular ends of the ischium (63) and of the pubis (64) are exposed, retaining their connection with the ilium (62) opposite the forty-third to the forty-seventh vertebræ on both sides. The femora (65) have been slightly dislocated forward, and part of the acetabula is thus exposed.

The bones of the hind fins have preserved their natural relative positions; those of the left side, with their part of the pelvic arch, being a little more backward in position than those of the right, agreeing, in this respect, with the pectoral limbs, and indicating some general movement of the matrix as the cause of such displacement.

Including the atlas and axis there are twenty-four vertebræ before that in which the pleurapophyses have risen, to articulate wholly with the diapophyses (Tab. XII, D). At the forty-fifth vertebra the rib again begins to articulate with the centrum; in the forty-sixth the parapophysis forms the lower half of the costal surface; in the forty-seventh it forms a larger proportion, and the whole costal surface is here suddenly increased in size, giving attachment to a short, slightly bent pleurapophysis of correspondingly and abruptly increased thickness; that of the forty-eighth vertebra is thicker and straighter, and, as the preceding riblet inclines towards its extremity, I conclude that their thick, abrupt, digital ends were ligamentously connected with the iliac bone, and that they therefore may be regarded as sacral vertebræ (Tab. IX, s, s). The remaining vertebræ, from the forty-ninth to the eighty-fourth, will be caudal; thus there may be reckoned 24 cervical, 24 dorsal, 2 sacral, and 34 caudal vertebræ, in the present species.

Perhaps the two vertebræ antecedent to the sacral, in which the centrum shows part of the costal surface, might be regarded as lumbar vertebræ.

The total length of the vertebral column, from the third cervical to the last caudal, following its slight undulations, is 9 feet 9 inches. The skull, from the hind end of the mandible to the fore end of the symphysis, or snout, is 1 foot 11 inches.

The first five or six cervicals, from the third, are more or less obscured by pyritic matter; their neural spines show intervals of from three to six lines; the upper margin of the spine rises obliquely from before backward, with the angle rounded off; it is thickest at the middle part, where it measures two lines; that of the fourth vertebra has a fore-and-aft diameter of seven lines, the same diameter of the ninth is one inch. The pleurapophyses of the tenth vertebra are about an inch in length, with a subcylindrical body, bent obliquely backward, and slightly tapering to an obtuse end. In the eleventh vertebra, the centrum of which is an inch in length, about five lines of free surface intervene between the costal and neurapophysial articulations. From the pleurapophysis to the summit of the neural spine it measures 2 inches 5 lines. At the twelfth cervical the pleurapophyses begin to send forward the process which marks what may be termed the neck or pedicle of the cervical rib.

At the fourteenth cervical the length of the centrum is 1 inch 5 lines; that of its pleurapophysis is 1 inch 9 lines; the fore-and-aft extent of the base of the neural spine is 1 inch 2 lines; the height of the spine is 1 inch 6 lines, and its thickness is 3 lines. The total height of the vertebra is 4 inches. These dimensions are gained by gradual increase from the tenth vertebra. In the nineteenth cervical the length of the centrum is 1 inch 6 lines, the space between the pleur- (ib. *pl*)) and neur- (ib. *np*) apophysial surfaces is 7 lines. From the lower part of the centrum to the summit of the neural spine (*ns*) is 5 inches; the length of the pleurapophysis is 2 inches.

The *Plesiosaurus rostratus* ranks with the section of its genus charaeterised by broad and short cervical vertebræ. The instructive characters derivable from this region will here be described as they appear in the fifteenth of the series (Tab. X, figs. 1—3). This vertebra gives the following dimensions:

	In.	lines.
Length of centrum	1	6
Height of terminal surface of ditto, or vertical diameter	1	7
Breadth of ditto	2	6
Breadth of the middle of centrum	2	3
From the under part of centrum to the summit of neural spine	4	0
Fore-and-aft extent of neural spine at its middle	1	2
„ „ neural arch from the end of one zygapophysis to that of the other	2	4
„ „ neural arch below the zygapophyses	1	1
„ „ costal surface	0	10
From the costal surface of the base of the neurapophysis	0	8

The terminal articular surface of the centrum is nearly flat, very slightly convex towards the circumference, and similarly concave at the centre; it is transversely elliptical, with a rather thin border, pretty closely co-adapted to that of the contiguous centrum. The sides of the centrum are moderately concave, the under surface is more deeply so; and this is further excavated on each side of an obtuse median ridge (*r*), near which the venous canals open into the large and deep ellipsoid fossæ. The outer boundary of these fossæ is formed by the lower border of the costal articular surface (Tab. X, fig. 3, and Tab. XI, fig. 2 *pl*). The costal surface (Tab. X, fig. 1, *pl*) presents an oval form, with the long axis parallel with that of the centrum, 10 lines in length by 8 lines in breadth, situated at the angle between the lateral and inferior surfaces, and divided by a smooth, non-articular trait of the lateral surface, of 8 lines in vertical extent from the neurapophysial surface of the centrum; this is defined below by a slightly curved subangular border, convex downward. The fore surface of the centrum presents a slightly fibrous character, not so smooth as in some other species, nor so irregular as in the *Pl. rugosus*, for example.

The neural arch is broad and low; the zygapophyses project from nearer the base

of the arch and centrum than in the *Pl. dolichodeirus* (Tab. III, fig. 4) or in *Pl. Bernardi* (for example, Monograph, 1862, Tab. IV, fig. 11), and their articular surfaces are more horizontal, the anterior ones (Tab. X and XI fig. 1, *z*) looking almost directly upward, the posterior ones (ib. *z'*) downward; in this character the present species resembles the *Pl. homalospondylus*. The neural spine is of subrhomboid figure, its height hardly exceeding the fore-and-aft breadth; the anterior border is convex, and rounded off into the upper one, with a scarcely marked angle; the posterior one is slightly concave, the angle between it and the upper border is blunted; the antero-posterior extent of the base of the spine is 1 inch 4 lines, the height of the spine is 1 inch 6 lines. The parapophyses (Tab. X, figs. 1 and 3, Tab. XI, fig. 1, *pl*) are not anchylosed to the centrum. Their head, or articular surface (ib. fig. 2 *pl*), forms the thickest part; the bone decreases as it stands outward, especially in vertical diameter, becoming flattened or depressed; it then bends backward, sending a short process forward, like the tubercle of the Crocodile's cervical rib, but developed from the same plane as the head; the backwardly contained body of the rib decreases in horizontal and increases in vertical breadth, presenting a broadly convex surface outwardly (Tab. X, fig. 3 *pl*). The length of the cervical pleurapophysis in the fifteenth cervical here described from the fore part of the head to the posterior point, is 2 inches; from the end of the tubercle to the posterior point is 1 inch 8 lines. The increase in the succeeding vertebræ is most in the pleurapophyses, next in the neural spines, then in the breadth of the vertebra, and least in the length of the centrum; this, indeed, varies somewhat, but not so much as appears in the figure 2 of Tab. XI, in which the matrix is left upon part of the inferior surface in two of the vertebræ.

Resuming the consecutive examination of the spinal column we find, in the twentieth vertebra (Tab. XII, 20), the costal surface rises nearer the neurapophyses (*np*); the rib has attained a length of 2 inches 8 lines. In the twenty-first (ib. 21) the costal surface reaches the neurapophyses (*np*), which contributes a little to its upper part by a diapophysial projection. The vertical extent of this costal surface is 1 inch, the length of the pleurapophysis is nearly 3 inches. In the twenty-second vertebra half the costal surface is formed by the diapophysis. The length of the rib (*d*) is 3 inches 9 lines; the anterior process or tubercle becoming shortened. It is shorter in the next rib (*pl*), the body of which is longer; and on the rib of the twenty-fourth vertebra it has disappeared. In the twenty-fifth vertebra (ib. D 1) the diapophysis (*d*) is prominent, and forms the entire costal surface. The ribs of this instructive series of six consecutive vertebræ have been dislocated from their articulations, apparently by the operation of the pressure which rotated the rest of the vertebræ from the vertical to the lateral position, but they retain their relative positions to each other, the end of one extending beyond and below the fore part of the next, and, in a greater degree, as the vertebræ approach the back. The sides of the neural spines of these vertebræ are roughened by irregular or granulate ridges, directed toward their

summit, which is bent backward. The dorsal vertebræ continue to increase in the length and size of the diapophyses, in the height of the neural spines, in the breadth and depth of the centrum, and, in a still greater degree, in the length of the ribs ; in every dimension, in short, except that of the length of the centrum, which, in the tenth dorsal, is 1 inch 10 lines, and in no dorsal vertebra exceeds 2 inches. The breadth of the centrum in the tenth dorsal is 3 inches ; the height, 2 inches 3 lines ; the articular surface is moderately hollow at the middle, and gently convex towards the periphery ; the neural spines gradually attain the height of $3\frac{1}{2}$ inches towards the end of the series, the fore-and-aft extent being about $1\frac{1}{2}$ inch near the summit, which is more thickened and truncate than in the neck, measuring, in some of these vertebræ, 9 lines in thickness. Both margins are concave at the lower half of the spine, and the intervals between those of different dorsal vertebræ average about three fourths of an inch at the narrower parts of the spines. The length of the diapophysis is about $1\frac{1}{2}$ inch ; it expands to its extremity, which is abruptly truncate, looking obliquely outward, backward, and a little downward ; it is flat, and rather rough, for ligamentous union with the rib ; subquadrate in form, averaging about an inch across. The ribs attain their greatest length from the twelfth to the fifteenth dorsal, where they are 1 foot 6 inches in length, with a simple expanded end, corresponding in shape and size with the diapophysial surface ; the body of the rib is subcylindrical, then subtrihedral, and again subcylindrical in shape, about 6 lines in diameter at the narrower part, and gradually enlarging at the distal third to the truncate extremity, which was ligamentously connected with the sternal rib. Some of the longest ribs have suffered fracture, and some contortion at their middle slender part, in the course of the cosmical pressure which has spread them out flat ; but they retain much of their natural curvatures on each side the vertebral column. After the thirteenth, the ribs gradually decrease to a length of $3\frac{1}{2}$ inches, in the last vertebra, in which the rib articulates wholly with the diapophysis (twenty-second dorsal), the breadth of this rib is 5 lines. Where the rib begins again to descend from the centrum, it continues to decrease in length in the first and second, in the latter of which it begins to gain in thickness. In the forty-ninth vertebra, counting from the skull, which vertebra I have indicated (Tab. IX, s) as the first sacral, the rib is 2 inches 6 lines in length, and 9 lines in least diameter ; its head is partly buried in the matrix, but the articular surface next the vertebra from which it is detached is 2 inches in vertical and 1 inch in longitudinal diameter, and the surface projects below, from the centrum, as it does above, from the neural arch. The borders of the terminal articular surfaces of the centrum are thicker and rougher than those of the dorsal or caudal vertebræ, indicating a stronger connection between the vertebræ from which the pelvic arch was suspended. The rib of the second sacral is straight, $2\frac{3}{4}$ inches in length, and 13 lines in the smallest diameter.

In the caudal vertebræ the neural spines gradually decrease in length, but more so in antero-posterior breadth, being longer, and with wider intervals at the basal half of

the tail than in the neck. The pleurapophyses continue to articulate in part with the neural arch to the tenth or twelfth caudal vertebra; the pleurapophyses are straight, and have gradually diminished to a length of $1\frac{1}{2}$ inch in the tenth caudal; they are flattened, and slightly expand towards the fore extremity, which, in the one above cited, there measures 10 lines across; the hæmapophyses are distinctly shown, those of each pair being separate, beneath the centrums of the seventeenth, eighteenth, and nineteenth caudals, forming part of that series where the neural spines are turned to the left. The first of these hæmapophyses has a length of 1 inch 9 lines, and a fore-and-aft breadth of 6 lines at its compressed, dilated, free extremity. The articular surface of the centrum of the twentieth caudal vertebra is exposed; it is gently concave, with a central depression, 1 inch 3 lines in vertical and nearly the same in transverse diameter, with an inferior border bevelled off at the fore part, for the articulation of the hæmapophyses. The ten terminal caudals show the lateral compression and flattening, with suppression, first of the posterior then of the anterior zygapophyses; next of the neural spine, and, in the last three or four, of the neural arch itself. Traces of hæmapophyses may be distinguished as far as the twenty-ninth caudal. This compression of the centrums would indicate, by cetacean analogy, some development of the terminal dermal expanse, but in a vertical, not horizontal, direction.

Reckoning the dorsal series of vertebræ as twenty-four in number, it constitutes rather more than one third of the whole extent of the spinal column; the thirty-four caudal vertebræ, of smaller proportions, constitute another third; the twenty-four cervicals are rather less than a third. The skull is equal in length to three fourths of the neck and to one sixth of the entire skeleton. The total length of the vertebral column is 9 feet 9 inches, the total length of the skeleton being 11 feet 8 inches.

The skull (Tabs. IX and XIII) is 1 foot 11 inches in length, 9 inches in breadth across the mastoids, $7\frac{1}{2}$ inches across the back of the orbits, but here it appears to have been somewhat flattened out by pressure. It is 5 inches 3 lines broad in front of the orbits, 2 inches across the narrowest part of the snout, which, from the fore part of the orbit, is $11\frac{1}{2}$ inches in length, and expands at its extremity to a breadth of $2\frac{1}{2}$ inches. This is the proportion of the snout, which gives the peculiar and distinctive character to the present species of *Plesiosaurus*, and which suggested *rostratus* as the specific name; in fact, the head, from the aspect exposed, resembles rather that of the Muschelkalk *Pistosaurus* than that of any of our heretofore known Liassic *Plesiosauri*.

The temporal fossæ are oblong, contracting anteriorly, and are there outwardly rounded off; in length 5 inches; in breadth, posteriorly, 3 inches. The subcircular orbits are 2 inches in diameter. The narrow elliptical nostrils are $1\frac{1}{2}$ inch in advance of the orbits. The upper and hinder boundary of the cranium, formed by the bifurcate parietal, and strong, overlapping mastoids, is convex superiorly, expanding as it proceeds outward. The middle part of the parietal rises into a sharp crest

between the temporal fossæ, and a continuation of the same crest, whose sides slope away from each other at a right angle, characterises the upper part of the frontal to midway between the orbits. The postfrontal bar, or flattened tract, dividing the orbital from the temporal fossæ, is an inch in breadth. The narrow nasals are divided by a medial suture, and, with the prefrontal and lacrymal, separate the orbit from the nostril.

The lower jaw has slipped from beneath the cranium, and, by the effect of the gradual pressure, has been turned, with the flatter left side upward. The angle projects beyond the articular surface 2 inches 3 lines, terminating obtusely, slightly bent, with the concavity upward, and 1 inch in thickness. The great part of the articular cavity of the right ramus is exposed, showing a transverse diameter of 1 inch 3 lines, and a fore-and-aft diameter of 10 lines: it is concave lengthwise, sinuous across. In advance of the articulation the ramus shows a depth of $1\frac{1}{2}$ inch, gradually increasing to that of 2 inches 3 lines, and then contracting vertically toward the dentary part; the deepest portion, formed by the angular and sub-angular elements, is situated about four inches in advance of the articular cavity, and there the thin outer parietes of the ramus have been crushed in, yielding to the superincumbent pressure.

The length of the dentigerous part of the jaw is 1 foot 2 inches; externally the dentary descends vertically from the sockets containing the teeth, but internally it swells out into a strong, convex, longitudinal tract, strengthening the alveoli, until the two dentaries meet at the symphysis. There is a longitudinal groove at the middle of the inner surface, below which the bone again swells out and is continued into the thick under surface of the dentary. The length of the symphysis is nearly 7 inches; and here the vertical extent increases, and terminates more sharply below. The vertical extent of the dentary, behind the symphysis, is 1 inch, the deepest part of the symphysis is $1\frac{1}{2}$ inch; the outer surface of the symphysis is coarsely and irregularly rugose; its upper border is scooped out at the alveoli for the larger teeth; on the left side there are about twenty-two sockets for teeth of different sizes; the smallest are behind, and the hindmost shows a straight crown (Tab. IX, fig. 6), sloping forward, from 4 to 5 lines long, with the usual longitudinal ridges of the enamel. The tooth in advance is slightly bent; the eighth in advance shows a crown, 9 lines in length; the fifteenth in advance (Tab. IX, fig. 4) shows a sudden increase of size, and greater degree of backward curvature; including this, eight teeth occupy the rest of the alveolar surface, which is coextensive with the symphysis. Here the teeth are divided by intervals of rather more than their own basal breadth; the largest tooth (ib., fig. 3), following the curvature, has a crown two inches in length. The longitudinal enamel-ridges begin at from one to two lines above the base of that covering of the crown, where it is smooth, and they terminate about the same distance from the apex; they are least developed at the outer, convex part of the upper half of the crown. Two of these large, laniary teeth project from the anterior alveolus, the outer and

anterior tooth being about to be shed. The right side of the symphysial part of the jaw (Tab. IX, fig. 2) contains nine teeth, the third, fifth, and seventh being the largest. The fifth (Tab. IX, fig. 5) measures $2\frac{1}{2}$ inches in length of crown, following the curve. The fourth and sixth teeth were emerging from sockets larger than themselves, and are successional teeth. The unusual length of the symphysis corresponds with the prolongation of the premaxillary above.

In the same locality and formation with the skeleton above described was discovered the portion of skull, corresponding in size, and, so far as it is preserved, in shape with that of the skeleton of the *Plesiosaurus rostratus*, to which species, therefore, I provisionally refer the specimen (Tab. XIII). It includes the basi-occipital, right ex-occipital, basi-sphenoid, portions of pterygoids, ecto-pterygoids, palatines, with fragments of the maxillary and of the right ramus of the mandible. In the figures of this specimen (Tab. XIII) the mandibular part is omitted. The left ex-occipital is wanting; the right (ib., 2) is displaced, so that the whole of the upper part of the basi-occipital (ib., 1) is exposed. This shows that the bases of the ex-occipitals are divided from each other by a narrow tract, and that the basi-occipital forms the whole of the condyle and of the median part of the floor of the epencephalic compartment of the cranium; this part of the bone (1) measures across its most contracted portion about three lines. The condyle is subhemispheric, with the transverse diameter rather the longest, and with a slight and irregular depression a little above its centre. The upper border of the condyle (fig. 1) is on a level with the advanced epencephalic surface (1) of the basi-occipital, from which it is divided by a shallow and narrow transverse channel; the lower border (fig. 2, *o*) projects abruptly downward, and is divided from the more advanced surface of the basi-occipital by a transverse furrow, three lines wide and four or five lines deep. The surface of the basi-occipital is covered by the posterior border of the pterygoids (24) which underlie it, extending backward, so as to leave only parts of the pair of rough and tuberous basi-occipital processes (*h*, *h*) exposed. The posterior part of the epencephalic surface of the basi-occipital (Tab. XIII, fig. 1, 1) is smooth and concave transversely; but, as it advances, it becomes irregular and expands, and apparently is divided by an irregular protuberance at the middle part. The neurapophysial surfaces (*n*, *n*) on each side are, as in the succeeding centrums, triangular, with the angles rounded off. About a line in advance of these is the 'harmonia,' or straight suture, indicating the flat synchondrosis by which the epencephalic unites with the mesencephalic centrum (basisphenoid, ib., 5), thus repeating the kind of union which attaches the centrum of the atlas to that of the axis vertebræ. The neural surface (5) expands to a greater breadth than it had attained in the basi-occipital, measuring fourteen lines across; it has a smooth, undulating surface, moderately concave in the middle, where it sinks below the level of the epencephalic surface (1). The sides of the mesencephalic surface are bounded by a narrow ridge, seemingly an exogenous growth from the centrum, as in some modern

Lacertilia, to which 'neurapophysial' ridges (Tab. XIII, fig. 2, *n*, *n*) may have been attached the neurapophyses, but retaining, as in these *Lacertilia*, more or less of their primitive histological fibro-cartilaginous condition. The under and lateral parts of the mesencephalic centrum, called 'basisphenoid,' are covered by the largely developed 'pterygoids' (ib., fig. 1, 24),—the diverging appendages of a more advanced cranial segment. The back part of the third or 'prosencephalic' centrum has coalesced with the second, the boundary-line being indicated by a shallow depression, which may have lodged the vascular appendage of the brain called 'hypophysis,' or 'pituitary gland.' The sides of this part of the centrum rise, neurapophysially, and terminate with a fractured and worn surface, and the rest of the centrum, answering to the cetacean 'presphenoid' (9), has been broken away. Beneath the fractured end of the presphenoid is the nasal 'meatus,' or canal (ib., fig. 1, *r*), which is divided below by the junction of the palatines (ib., fig. 2, 20, 20) with the pterygoids (ib., 24, 24), so as to open upon the roof of the mouth by a pair of posterior or palatal nostrils 'palatonares' (ib., *r*, *r*). These are of a narrow, elliptical form, with the long axis longitudinal, but slightly, inclined 'mesiad,' or converging anteriorly, pointed behind, 1 inch 6 lines in long diameter, 7 lines across their widest part, and separated anteriorly by a tract of bone 9 lines across; from the posterior end of the 'palatonares' to the same part of the basi-occipital tuberosity is 1 inch 5 lines. The palatines (ib., fig. 2, 20, 20), where they give attachment to the pterygoids, are narrow, rather thick, with a shallow median channel, bounded by low, lateral, obtuse risings; external to these the palatines form the anterior ends of the 'palatonares,' and thence expanding, and flattening as they stretch forwards, they unite laterally with the ectopterygoids (25, 25). The pterygoids (24, 24), which form the inner and posterior boundaries of the palatonares, expand as they pass backward, become thinner and flatter, and retain a sutural union along the mesial line until they reach the preccondyloid fossa of the basi-occipital; underlying and concealing from view, inferiorly, the basi-presphenoid and major part of the basi-occipital. These 'basilar' plates are slightly concave from side to side, and are divided from the 'tympanic' processes (24′, 24′) by a rising of bone, hardly to be called a ridge; this is chiefly formed by the concavity or sinking of the surface at the commencement of the under part of the 'tympanic' process, which also gradually contracts in breadth as it extends backward and outward to abut against the tympanic pedicle (28), which is wedged at its upper or cranial half between the pterygoid (24) and par-occipital (3).

The ectopterygoid (ib., fig. 2, 25) articulates with the pterygoid near the posterior part of the palatal nostril, where it is about seven lines in breadth; this joint has been put out by pressure on the right side and the ectopterygoid dislocated downward; the corresponding part is broken off on the left side, where it overlaps the pterygoid, forming the outer boundary of the palatal nostril. The ectopterygoid expands as it advances forward; curving, mesially, round the fore part of the nostril to join the

palatine (20), and laterally to join the maxillary (21), of which a fragment is preserved in this crushed specimen. The lower opening of the temporal fossa is bounded mesially in nearly equal proportions by the pterygoid and ectopterygoid.

Estimating the length of the skull in the present specimen at two feet, about six inches in length of the hind part is here preserved; and the palatal nostrils open chiefly upon the hinder half of this part. In their posterior position, therefore, they agree with those in *Teleosaurus,* but differ in being divided by the medial productions of the palatines and pterygoids, and in not being confluent, as a single aperture, as in the *Crocodilia;* thus they exemplify the more general Reptilian character as it is preserved in our modern *Lacertilia.*

In the *Nothosaurus* the palatonares are two; but they open upon the anterior fourth part of the bony palate, having their hinder boundary formed by the palatines instead of their front one. In *Pistosaurus* the palatonares are situate about midway between the fore and back part of the long and narrow bony palate. In all *Sauropterygia* the pterygoids present much of their crocodilian character in their posterior extension and expansion, underlying the posterior cranial centrums and covering, in this way, in *Plesiosaurus,* more of the basi-occipital than in the crocodiles. Some portions of long, slender, subcompressed bones adhering to the present instructive fragment of the plesiosaurian cranium may have belonged to the hyoidean arch; one of them (40) adheres to the bony palate, and partly conceals the left palatal nostril in fig. 2.

Pectoral and pelvic arches and limbs (Tab. IX).

The scapula (Tab. IX, 51) is 5 inches in length; smooth and convex externally at its narrow upper part, where it shows a breadth of 10 lines; it rapidly expands to a breadth of 3 inches at its humero-coracoid extremity, which overlaps, as before mentioned, the head of the dislocated humerus. The outer surface of the articular end of the scapula is roughened by longitudinal ridges.

The humerus (ib., 53), showing a breadth of 1 inch 9 lines where it emerges beneath the scapula, expands to a breadth of 4 inches where it is articulated to the antibrachial bones; its anterior border is straight, less convex at the distal half than in *Pl. dolichodeirus;* less expanded at the distal end than in *Pl. homalospondylus.*

The radius (ib., 54) is 3 inches 2 lines in length, 2 inches broad at its proximal end, 1 inch 9 lines at its distal end; with a thin, straight, somewhat irregular anterior border, and a thicker, smooth, concave posterior border. The ulna (ib., 55) presents the usual reniform figure, with the concavity toward the radius; it is of the same length as the radius, but is flatter; 2 inches 3 lines across its middle part; the margin next the radius is rather more concave than that which it opposes; the

opposite margin of the ulna is very convex; the distal end is divided by a low angle between the surfaces for the outer and middle carpals of the proximal row.

The carpal bones are six in number, three in each row. The proximal ones are the largest, but, of this row, the radial carpal, or 'scaphoid,' is least; it is of a transversely oblong figure, with its distal border divided by a low angle between the radial and the middle bones of the second row; this relation is better shown in the right than in the left pectoral fin. The middle proximal carpal, or 'lunare,' is the largest, of a sub-hexagonal form; the shortest side, toward the radius, is concave; the side opposite the radial carpal is rather convex; the other facets for the ulna, ulnar carpal ('cuneiforme') and the two larger carpals of the second row, are nearly straight. The three carpals of the second or distal row increase in size from the radial to the ulnar side of the waist; the outermost being surrounded by three carpals and three metacarpals; the metacarpal of the fifth digit extending along its ulnar side to articulate with the ulnar carpal of the first row. In its relations to the metacarpals, the largest of the second row resembles the 'magnum' and 'unciforme' combined, of the mammalian carpus. The next in size answers to the 'trapezoides,' supports the second metacarpal, and, at its opposite border, fills the interspace between the radial and middle carpals of the first row. The radial carpal of the second row is the smallest of all; it is wedged between that of the first row, the first metacarpal and the middle carpal of the second row: it answers to the 'trapezium.'

The first metacarpal (ib., 56) is the shortest, 1 inch in length, it supports two phalanges, the last of which is 10 lines in length; the whole length of this digit, including the metacarpal, is 2 inches. The second metacarpal is 1 inch 9 lines in length, and supports six phalanges, the last being 4 lines long; the total length of this digit, including the metacarpal, is 10 inches 6 lines. The middle metacarpal is 1 inch 10 lines in length, it supports eight phalanges; the total length of this digit, including the metacarpal, is 10 inches 6 lines. The fourth metacarpal is 2 inches in length, it supports seven phalanges; the total length of the digit, including the metacarpal, is 10 inches. The metacarpal of the fifth digit is $1\frac{1}{2}$ inch in length, its proximal breadth is 1 inch; that of the first metacarpal being half an inch, and that of each of the three intermediate metacarpals ranging from 9 to 10 lines; the outermost metacarpal supports seven phalanges: the total length of the digit, including the metacarpal, is $9\frac{1}{2}$ inches; the fifth metacarpal, besides being shorter and broader than the three middle ones, is more convex, and obliquely bevelled off at its proximal end, the radial side being shorter than the ulnar one. The phalanges of the fifth digit are more concave at their outer or ulnar border than the others. The first metacarpal is more concave at its radial border. All the phalanges are flattened and expanded at their extremities, the outer surface showing linear impressions, the middle part being smooth. The total breadth of the carpus is 4 inches 5 lines. The total length of the hand is 1 foot 1 inch. The total length of the pectoral limb seems to have been about

2 feet. It is much shorter in proportion to the trunk (as reckoned from the first dorsal (ib., fig. 1, D) to last sacral (ib., S) than in the *Plesiosaurus homalospondylus* (Tab. V), and differs in the more proximal position of the metacarpal of the fifth digit, and in the smaller size of the radial carpal of the distal row.

Like the scapula in the pectoral arch, the ilium (Tab. IX, 62) is the smallest bone of the pelvic one; it is 5 inches in length, $1\frac{1}{2}$ inch across the obliquely truncate upper (proximal or sacral) end, it contracts to a diameter of 9 lines at its middle, and then expands to a breadth of 2 inches 4 lines, with proportional thickness, at its lower acetabular end. The stem is subcompressed, convex transversely, and also longitudinally at the upper half, which shows a low ridge externally, and is longitudinally striate near the margin of the surface connected with the sacral pleurapophyses, from which, as before stated, it has been dislocated. The acetabular end preserves its natural connections with the corresponding thickened part of the ischium (ib., 63), which on both right and left sides is interposed between the ilium and pubis. The rough acetabular surface is nevertheless continued from the ischium upon the pubis, for about two inches of the contiguous border. The head of the femur is applied to the ischio-pubic surface in both limbs, yet the better proportioned articular depression is that formed by the ilium and ischium, from which it seems as if the femur had been dislocated forward. As, however, the mode of attachment has been by a ligamentous mass, this may have converged from the whole of the antero-posteriorly extended acetabular surface to the head of the thigh-bone, allowing a certain freedom of play of the bone forward and backward; the diameter of such acetabular surface, lengthwise, is 5 inches, the greatest vertical diameter is 3 inches.

The ischium (Tab. IX, 63), as it passes from the acetabulum mesiad, loses its thickness and expands into a plate of the usual triangular form, the posterior apex of which is seen on the left side behind the two overlying sacral ribs, stretching as far back as the ilium (ib., 62); from this apex, or angle, to the acetabular junction with the pubis, the ischium measures 8 inches. Pyritic matter intervenes between the ischium and sacral ribs, on the left side.

So much of the pubis (Tab. IX, 64) as is visible on the left side exhibits the usual subcircular discoid shape, with the two facets on the thickened part of the margin, one for articulation with the ischium, the other completing the fore part of the acetabular tract. The broadest part of the exposed pubic disk measures 6 inches lengthwise.

The femur (Tab. IX, 65) is 9 inches 9 lines in length. A longitudinal notch feebly marks out a trochanteric part of the thick, convex, articular head; this is coarsely pitted for the ligamentous insertions. The shaft contracts, chiefly losing thickness, and becoming lamelliform as it expands in breadth to the distal articular surface. This is convex, curving in a greater degree at its hinder part. Both anterior and posterior borders of the shaft are concave; the former least so, but to that extent differentiating the femur from the humerus, in which it is straight, or rather convex.

The distal breadth of the femur is 4 inches 8 lines; the non-articular surface is smooth, except near the two ends, where there are rough, longitudinal ridges and depressions, indicative of ligamentous insertions.

Both tibia (Tab. IX, 66) and fibula (ib., 67) are broader in proportion to their length than their homotypes in the fore limb. The posterior distal angle of the fibula is more decidedly truncate, for articulation with the middle tarsal, than is the corresponding part of the ulna. The inter-osseous space is a long ellipse with pointed ends, about an inch in width across the broadest part.

The tarsus (Tab. IX, 68), like the carpus (ib., 56), consists of six bones, in two rows of three each. The tibial bone of the first row is broader, in proportion to its length, than its homotype in the carpus; and this is the proportional character of all the bones of the tarsus, save that which intervenes between the fibula (67) and the fifth digit (69), the metatarsal of which passes outside the distal tarsal series.

The metatarsal of the innermost tibial, or first digit, is 1 inch 4 lines in length, 10 lines in breadth, and supports three phalanges; the total length of the digit, including the metatarsal, is 4 inches 8 lines. The metatarsal of the second digit is 1 inch 9 lines in length, and supports six phalanges, the last being 4 lines in length; the total length of this digit, including the metatarsal, is 8 inches 6 lines. The metatarsal of the mid-digit is 2 inches in length, and supports nine phalanges; the total length of this digit, including the metatarsal, is 1 foot. The metatarsal of the fourth digit is 1 inch 11 lines long; the fibular side of its base is more produced than in the others; it supports a digit of eight phalanges, and this, including the metatarsal, is 1 foot 1 inch in length; the metatarsal of the fifth digit is 1 inch 10 lines in length, and supports six phalanges, the last of which is broader and flatter than in the other digits; the total length of the fifth digit, including the metatarsal, is 10 inches 2 lines. The breadth of the leg is 5 inches 5 lines; the length of the tibia 3 inches; that of the fibula 2 inches 9 lines. The breadth of the metatarsus is 4 inches 7 lines. The total length of the hind limb is 2 feet $4\frac{1}{2}$ inches. The hind limb, though longer and larger than the fore limb, repeats the character of relative shortness in proportion to the trunk, as engraved with the same parts in *Plesiosaurus homalospondylus*. The neural spines of the trunk are shorter, with wider intervals, exemplifying the superior vigour and locomotive power of the longer-necked and larger-finned species (Tab. VIII.)

We see in *Pl. rostratus* a correlation of the size of the head with that of the anterior laniary teeth, and with the shortness of the neck. But the head is proportionally less compared with the trunk, and the neck is shorter, and has fewer vertebræ, than in the *Pl. macrocephalus*.* These characters, with the greater lengthening and attenuation of the muzzle in *Pl. rostratus*, indicate a nearer step in affinity toward the Teleosaurian marine reptiles.

* 'Geological Transactions,' 2nd series, vol. v, pl. xliii.

PLESIOSAURUS RUGOSUS, *Owen*. Tabs. XIV and XV.

This species, originally indicated by characters of detached vertebræ,* has received ample elucidation from the fine specimen (Tab. XIV) presented by His Grace the Duke of Rutland, K.G., to the British Museum. It was obtained from the zone of Lower Lias of Leicestershire, characterised by the *Ammonites stellaris*, in the neighbourhood of Granby.

This specimen of the *Plesiosaurus rugosus* presents a similar condition to that of the *Pl. dolichodeirus* decribed by Conybeare,† save that the head is not preserved in advance of the small, scattered vertebræ of the anterior part of the neck; about five-and-twenty vertebræ of this region preserve their consecutive arrangement, most of them in almost a straight line. The vertebræ of the trunk have suffered a greater degree of dislocation, and, the specimen having been exposed in a prone position, they are so dispersed as to permit to be seen the upper or inner surface of the coracoids, the abdominal ribs, and the pubic and ischial bones. Two thirds of the caudal vertebræ show the same scattered and dislocated condition; but nine near the end of the tail have preserved their natural position, as consecutively articulated, and apparently their true relative position to the trunk. The four paddles are preserved outstretched, as naturally articulating with their respective arches of support, with the superior or external surface of the bony framework exposed.

The cervical vertebræ, which have retained their natural consecutive arrangement and juxtaposition, have undergone the same partial rotation as is observable in most Plesiosaurian skeletons from Liassic beds, presenting their broadest surface or sides to view; the neural spines have here rotated toward the left side. Besides the twenty-five cervical vertebræ which are more or less consecutive, three or four are huddled in a heap at the base of the neck, and five or six are scattered at its fore part. From the size of the articular surface of the foremost of these, which measures but six lines in diameter, as well as from so much of the length of the neck as is demonstrated, it may be inferred that the head was small, as in the *Pl. dolichodeirus*.

Cervical vertebræ (Tab. XV).

One of these vertebræ, corresponding in position to the fifteenth cervical of the *Pl. rostratus* (Tab. X), was carefully wrought out of the matrix of the specimen Tab. XIV, and is represented of the natural size in Tab. XV. Its proportions show that the present species, like *Pl. dolichodeirus* and *Pl. Hawkinsii*, belongs to the section

* 'Report on British Fossil Reptiles,' 1839; 'Reports of the British Association,' 8vo, 1840, p. 82.

† Tom. cit.

characterised by intermediate proportions of the centrum, neither "long," as in *Pl. homalospondylus*, nor "short," as in *Pl. rostratus* and *Pl. planus*. The following are the dimensions of this vertebra:

	In.	lines.
Length of centrum	1	9
Height or vertical diameter of terminal surface of ditto	1	9
Breadth of ditto	1	10½
„ the middle of centrum	1	7
From the under part of centrum to the summit of neural spine	4	4
Fore-and-aft extent of neural spine at its middle	1	4
„ „ „ arch from the end of one zygapophysis to that of the other	2	6
„ „ „ arch below the zygapophyses	1	3
„ „ costal surface	0	7
From the costal surface to the base of the neurapophysis	0	11

The free or non-articular surface of the centrum shows near the margins of the terminal surfaces the strongly marked rugous character which originally suggested the specific name in the detached vertebræ. The irregular risings of bone lie chiefly in the direction of the axis of the vertebra, and project so as to come into view exterior to the articular surface in an end-view of the centrum, as in Tab. XV, fig. 2. The sides and under part of the centrum are moderately concave lengthwise. The contour of the terminal articular surface is circular; its border is thick and convex, leading to a moderate concavity, with the central part rising into a slighter convexity. The costal pits (*pl*) are of a full elliptical form, with a slightly prominent margin, situated near the lower surface of the centrum, a little nearer the hind than the fore end, and with twice their own vertical diameter intervening between them and the base of the neurapophysis (*np*). This part of the side of the centrum is traversed by a low, longitudinal rising, a little nearer the neur- than the pleur-apophysis. The venous orifices on the under surface of the centrum (Tab. XV, fig. 4) are two and a half lines apart, with an intervening low, obtuse, longitudinal ridge, and are not situated in definite depressions. The lower border or base of the neurapophysis has not the angular form seen in *Pl. Hawkinsii* and *Pl. dolichodeirus*, but is curved. The neurapophysis rises, with both fore and hind borders vertically concave, transversely convex, about five lines above the centrum before giving off the anterior zygapophyses (*z*); the posterior arcs (*z'*) come off, as usual, a little higher. The neural spine is subquadrate, more angular between the fore and upper margins than in *Pl. rostratus* (Tab. X, fig. 1); the thickness of the spine is shown in Tab. XV, fig. 2; the front border is sharp. The chief variety observable in cervical vertebræ of the present species is the presence of the longitudinal groove bisecting the costal surface. The articular surface of the centrum in every cervical vertebra where it is exposed in the present skeleton repeats

the character of the one described; but some, at the base of the neck, have the central rising rough, and with a small pit in the middle. The same character is continued throughout the dorsal series, and the concavity is exaggerated in the vertebræ of the tail, which are, however, more concave than the others in all *Plesiosauri*.

	Ft.	In.
The total length of the specimen preserved is	10	6
The length of the cervical region preserved is	4	0
From the fore part of the coracoid to the hind part of the ischium . .	3	6
From the ischium to the end of the tail as far as preserved	3	3
The transverse breadth of the pubic bones across their broadest part is . .	1	$1\frac{3}{4}$
The fore-and-aft diameter of pubis at its middle part is	0	$5\frac{1}{2}$

Scapular arch and appendages (Tab. XIV).

The humerus (Tab. XIV, 53) is 10 inches long, $2\frac{1}{4}$ inches across its middle narrowest part, and $4\frac{3}{4}$ inches across its distal broadest part. The outer part of the head is somewhat produced, with a slight longitudinal depression on each side; its surface is tuberous and rough; there is a low tuberosity on the hind part of the humerus, below its head. The contour of the anterior border of the bone is nearly straight, slightly wavy, first concave, then convex, again concave and more convex as it is rounded off to the lower border. The posterior margin is more deeply concave from the upper tuberosity to the posterior angle, which is rounded off. The distal margin, convex in a general way, has its two surfaces sufficiently defined for the radius and ulna; they do not, however, meet at so well-defined an angle as in some species; a space of about an inch intervenes here between the radius and ulna in both right and left limbs, whereas they meet and touch each other in the *Pl. dolichodeirus* (fig. 5) and *Pl. Hawkinsii* (fig. 6). The shaft of the humerus shows a tolerably smooth and longitudinally fibrous surface, but has a rough tuberculate character for about an inch and a half from the distal articulations.

The radius (Tab. XIV, figs. 1 and 2, 54), 4 inches in length, is 2 inches 9 lines across the proximal end, 1 inch 10 lines across the distal end, 1 inch 6 lines across the middle. The radial or anterior margin is produced and somewhat thickened below the head, making the margin beyond it concave half way towards the distal end; the posterior or ulnar border is uniformly and moderately concave; the distal border of the radius is straight from its ulnar angle to near its radial one, where it becomes convex, that angle being, as it were, cut off. This distal border is most closely articulated, seems, indeed, partially confluent, with the scaphoid. The ulna (Tab. XIV, figs. 1 and 2, 55) would present its usual reniform shape, were it not that the proximal angle of the posterior or ulnar border is produced into a sort of olecranon (fig. 2, 55′). This process is separated by a fissure or fracture from the body of the bone; but as this

occurs in the same place and with the same course in both forearms, I infer it to be natural, and that the quasi-olecranon was of the nature of a sesamoid, closely articulated with the body of the ulna. The extreme length of the ulna, from the apex of this part or process (55′) is 5 inches; the greatest breadth of the ulna 3 inches. The proximal articular surface joins the ulnar facet of the humerus, beyond which the olecranon projects. The distal surface of the ulna articulates with the lunare (*l*), the cuneiforme (*c*), and with an ossicle (*p*) wedged into the interspace posteriorly between it and the ulna, which ossicle may represent the pisiforme. With the exception of about one third of the middle of the shaft, the exposed surface of both radius and ulna is roughened by coarse rugæ and small tubercles.

The carpus includes eight ossicles. The scaphoid (fig. 2, *s*) is an oblong bone, with its dimension greatest transversely, viz., 2 inches, longest at its ulnar side, which is 1 inch 3 lines, with a slight angular projection at its free radial border. The lunare (ib., *l*) is subreniform, with the concavity, representing the "pelvis of the kidney," completing the lower part of the inter-osseous space, for the radius and ulna are separate below as well as above, and for a greater extent, the radius extending for nearly an inch below or beyond the ulna. The rest of the circumference of the lunare is divided more or less distinctly into its articular surfaces for the radius, scaphoides (*s*), trapezoides (*z*), magnum (*m*), cuneiforme (*c*), and ulna. The ulnar surface has a sigmoid form. The lunare (*l*) is larger than the scaphoid. The cuneiforme (*c*), about the size of the lunare, has a subhexagonal shape; the two proximal sides articulate with the ulna and pisiforme (*p*), the radial side with the lunare, the ulnar side with the unciforme (*u*), the two distal sides with the magnum (*m*), and the base of the fifth metacarpal (*v*), which, as in some other *Plesiosauri*, ascends above the rest to this connection, severing, so to speak, the unciforme (*u*) from the magnum (*m*). The pisiforme (*p*) is a subtriangular small bone, wedged into the outer interspace between the ulna and cuneiforme. In the distal row of carpals the trapezium (*t*) is subquadrate, broader toward the scaphoid, narrower where it supports the first metacarpal (1); it is about half the size of the scaphoid. The trapezoides (*z*) is also subquadrate, but of larger size, articulating with the scaphoid, trapezium, the ulnar angle of the base of the first metacarpal, wholly sustaining the second metacarpal, articulating with the radial side of the base of the third metacarpal, with the os magnum (*m*), and with the lunare (*l*). The os magnum (*m*), of similar size, is hexagonal; the two proximal surfaces articulate with the lunare and cuneiforme, entering the angle which they leave; the two distal surfaces articulate with the third and fourth metacarpals; the radial side with the trapezoides, the ulnar side with the corresponding part of the base of the fifth metacarpal; the displaced outermost bone of the distal row is limited to its articulation with the ulnar border of the cuneiforme (*c*); it is the smallest of the carpal series.

The bones of the digits are small in comparison with those of the carpus and forearm. The entire breadth of the carpus being 6 inches 5 lines, that of the middle of

the metacarpus is 5 inches in the left hand, and but $4\frac{1}{2}$ inches in the right, both being preserved in their natural connections as they were buried, but one showing a more expanded, the other a more contracted, condition of the fin.

The first metacarpal (Tab. XIV, fig. 2, I) is 1 inch 9 lines in length, and supports two phalanges; the total length of that digit, including the metacarpal, being 4 inches 3 lines. The second metacarpal (ib., II) is 2 inches 3 lines in length; it supports five phalanges; the total length of the digit, including the metacarpal, is 9 lines. The third metacarpal (ib., III) is 2 inches 8 lines in length; it supports five phalanges; the total length of the digit, including the metacarpal, is 9 inches 9 lines. The fourth metacarpal (ib., IV) is 2 inches 5 lines in length; it supports four phalanges, and is the same length with the preceding. The fifth metacarpal (ib., V) is 3 inches 3 lines in length, with its ulnar margin more deeply concave than in the others; it supports four phalanges, most of which show the same deeper concavity, with a greater production of the ulnar ends of the articular expansions; the total length of this digit is 8 inches 6 lines; a distal phalanx is wanting in it, and the same may likewise be the case with the others.

There is a want of precise symmetry in the proportions of the right and left fore paddles, those of the right being longer and somewhat slenderer than those of the left.

The whole of the outer surface of the carpal bones is rugose, as is the chief part of that of the metacarpals and phalanges. The total length of the bones of the right pectoral limb, as here preserved, is 2 feet 3 inches; the breadth of the antibrachium is 6 inches 6 lines; that of the carpus 6 inches; that of the metacarpus 5 inches; the interspace between the heads of the two humeri is 1 foot 6 lines.

Pelvic arch and limbs (ib.).

The iliac bones (Tab. XIV, fig. 1, 62), dislocated by pressure, lie in the axis of the trunk, parallel with the ischia (ib., 63); the vertebral end of the ilium is broader but less thick than the acetabular one; the length of the bone is 4 inches 10 lines, the breadth of the vertebral end is 3 inches 6 lines; the breadth of the acetabular end is 2 inches. The surface here exposed, probably the outer or posterior one, shows a slight concavity on the vertebral expansion, where the bone is smooth; beyond, it becomes longitudinally striate, and rugose or tuberculate near the acetabular extremity; this is thickened and obscurely divided into the rough synchondrosal surface for the ischium, and the corresponding somewhat smaller surface for the ligamentous attachment of the femur.

The ischium (ib., 63) is flat, and of the usual elongate, triangular form; it joins its fellow by its straight inner side having the posterior angle rounded off; the outer, obtuse, non-articular border presents a sigmoid curve, concave near the ilium. The anterior shorter border is emarginate in the middle, where it forms the posterior boundary of the obturator foramen (ib., *o*), the straight articular parts of this side

joining the corresponding parts of the pubis; the outer acetabular angle is produced, and terminally expanded and thickened to form the articular surfaces for the ilium and femur.

The pubis (ib., 64), as in other *Plesiosauri*, is broader and larger than the ischium, with the medial or symphysial margin straight, measuring six and a half inches in extent; the anterior and external free margin is convex; the posterior margin is more deeply excavated than the opposite one of the ischium, forming a greater part of the circumference of the obturator foramen; the angle between the posterior and outer borders is thickened, to contribute the anterior part of the acetabulum. This rough and ill-defined articular surface for the femur is thus formed, as usual, by the three constituents of the pelvis.

The femora (ib., 65) here, as in some other *Plesiosauri*, have the head resting against the ischio-pubic part of the acetabulum, the ilia being placed about an inch further back. The femur, 10 inches in length, is 1 inch 9 lines across the narrowest part of the shaft, and expands to a breadth of 4 inches 9 lines distally; the outer (here the upper) part of the head is produced, and behind it is a longitudinal depression. The surface, for two inches or more from the distal end, is rugose, with longitudinal ridges breaking up into tubercles; both anterior and posterior borders are concave; the latter is the shorter border. The distal border is more regularly convex, and in a greater degree than in the humerus.

There is an interval between the proximal ends of the tibia and fibula, and a wider one between their distal ends, the interosseous space being considerable, as in the forearm. Here, also, the tibia (ib., 66), like its homotype (ib., 54), has a more distal extension. Its length is 3 inches 11 lines, its proximal breadth 2 inches 8 lines. The anterior proximal angle is somewhat produced; the anterior orbital border is slightly concave; the posterior one is more so. The fibula (ib., 67), like the ulna, departs from the ordinary reniform figure by the production of its fibular proximal angle (67′); this is not separated from the rest of the bone in the left leg, but it is so by what appears to be a crack in the right leg, and yet so as to indicate that such crack is in the place of an original epiphysial junction. The length of the fibula, including this process, is 4 inches 4 lines; the length of the concave tibial border of the fibula in a straight line is 2 inches 3 lines. As great a proportion of the exposed surface of the leg bones is rugose as is that in the bones of the forearm. Between the tibia and the tarsal bone supporting the first metatarsal there is a vacant space in both limbs, which, in the right limb, is partially occupied by a tubercle of bone. This we may regard as the beginning of ossification of a fibro-cartilaginous homologue of a naviculare (Tab. XIV, fig. 3, *s*). The homotype of the lunare (*a*) completes, by a free concave part of its border, the distal end of the inter-osseous space. This tarsal (*a*), which we may call "astragalus," articulates with the tibia (66); but to a greater extent and by a more definite straight border, with the fibula (ib., 67); posteriorly with the

calcaneum (*cl*), distally with the two outer bones of the distal row of tarsals. The bone (*cl*) which I have called "calcaneum" is the homotype of the cuneiforme in the carpus, which it resembles in size and shape; it articulates chiefly with the astragalus (*a*) and ecto-cuneiforme (*ec*); it seems to touch the fibula (67) by a small part of its periphery; and in the angle between it and the fibula is wedged an ossicle (*cl'*), answering to the pisiforme in the wrist and to the apophysial part of the calcaneum in the higher Vertebrates. The distal row of tarsals includes but three bones. The first (*ci*), the homotype of the trapezium, I call "ento-cuneiforme;" it articulates with the rudiment of the naviculare (*s*), and supports the metatarsal of the tibial or first toe (*i*). The next bone, "meso-cuneiforme" (*cm*), of larger size, supports the second and part of the third metatarsal, articulates with the ento-cuneiforme (*ci*), and more intimately and largely with the ecto-cuneiforme (*ce*). This (*ce*) is the largest of the three; it supports the fibular half of the base of the middle metatarsal, the whole of the base of the fourth metatarsal, and the tibial side of the base of the fifth metatarsal; it articulates also with the meso-cuneiforme (*cm*), astragalus (*a*), and calcaneum (*cl*); it is plainly the homotype of the os magnum in the wrist. The homotype of the unciforme, if it existed, must have articulated with the posterior or fibular margin of the calcaneum, but it is not present in either limb.

If we regard the largest of the distal tarsal series, supporting the fourth and part of the third and fifth metatarsals, as the "cuboides," we must then consider its obvious homotype in the wrist (*m*) to be the unciforme. The bone here called "meso-cuneiforme" (*cm*), which articulates with both second and third metatarsals, will then be the "ecto-cuneiforme," and the bone (*ci*) will be the two other cuneiform bones connate; in like manner its homotype, called "trapezoides" in the wrist, which has a similar relation to the second and third metacarpals, will be the trapezoid and trapezium connate, but in that case the outermost ossicle (fig. 2, *u*) of the distal part of the carpus would be a supernumerary without a name. I therefore prefer and adopt my first homologies.

The outer surface of the tarsals, except the middle of the calcaneum, is rugose. The first metatarsal (ib., *i*) is 1 inch 9 lines in length; it supports two phalanges; the total length of the toe, including the metatarsal, is 4 inches 9 lines. The length of the second metatarsal is 2 inches 3 lines; three of its phalanges are preserved; it is more distal in position than the first by about 4 lines. The middle metatarsal is 2 inches 5 lines in length; four of its phalanges are preserved. The fourth metatarsal, 4 inches 6 lines in length, has the fibular part of its base more extended, and that margin of the shaft is more concave; four phalanges are preserved, and the length of the digit, including the metatarsal, is 10 inches. The fifth metatarsal is 2 inches 5 lines in length; the tibial angle of its base is truncate, the fibular one is much produced and tuberous; the fibular margin is deeply concave; only one phalanx is preserved.

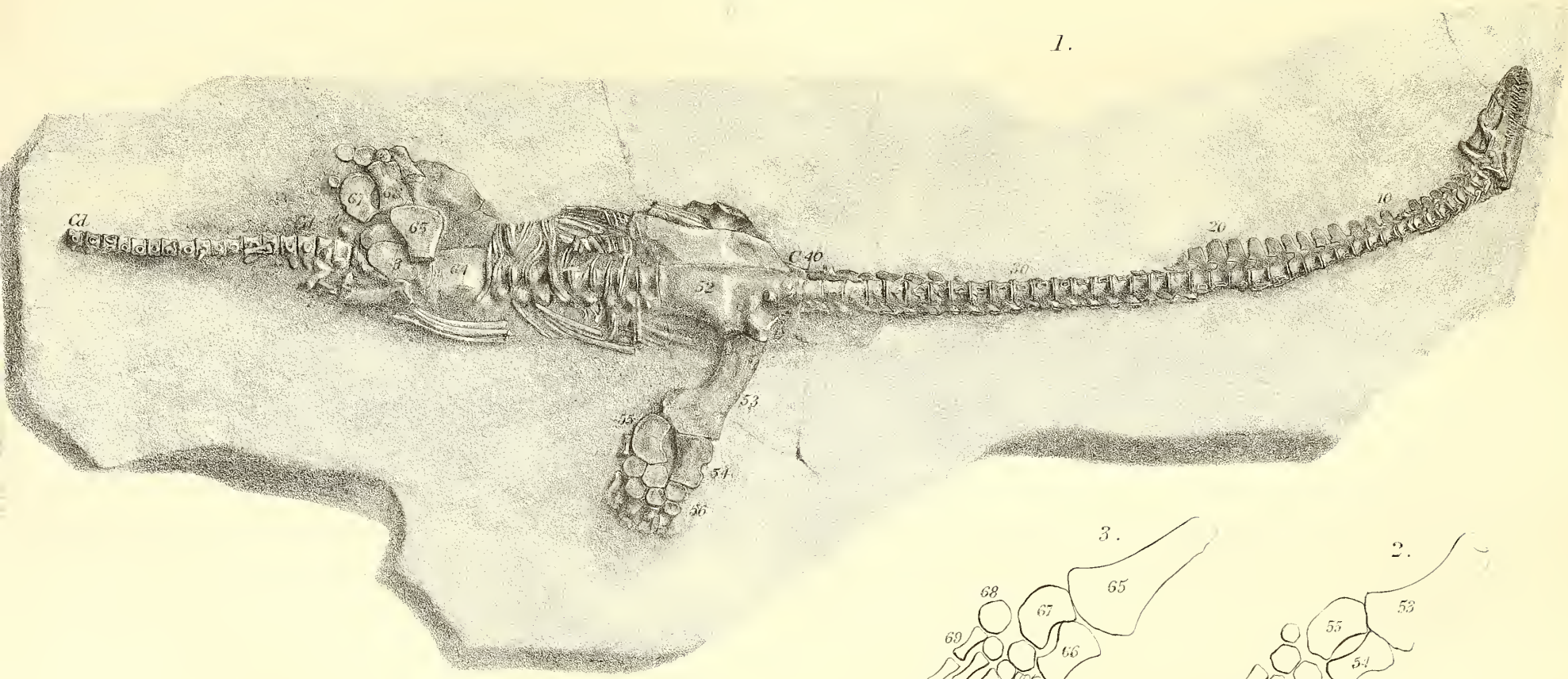
TAB. I.

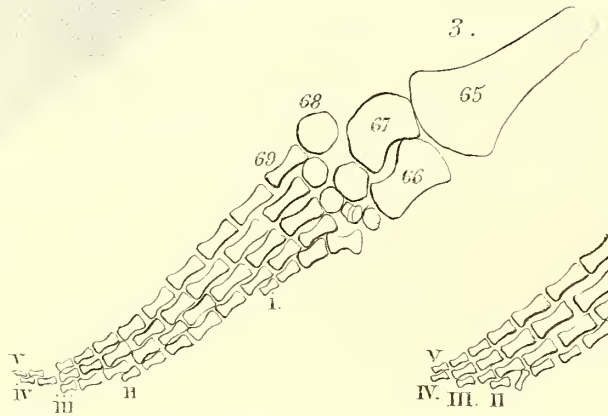
Plesiosaurus dolichodeirus.

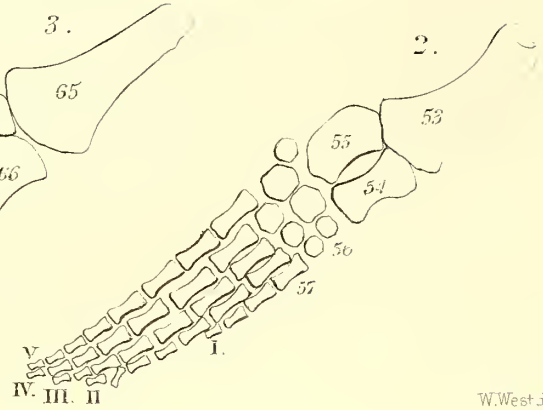
Fig.

1. Skeleton (No. 3), 1-10th nat. size.
2. Outline of bones of fore paddle of the skeleton described by CONYBEARE (p. 1), 1-8th nat. size.
3. Outline of bones of hind paddle, ib., ib.

From the Lower Lias of Lyme Regis. In the British Museum.







Scale.
0 1 2 feet.

J.Dinkel, del. et lith.

W.West imp.

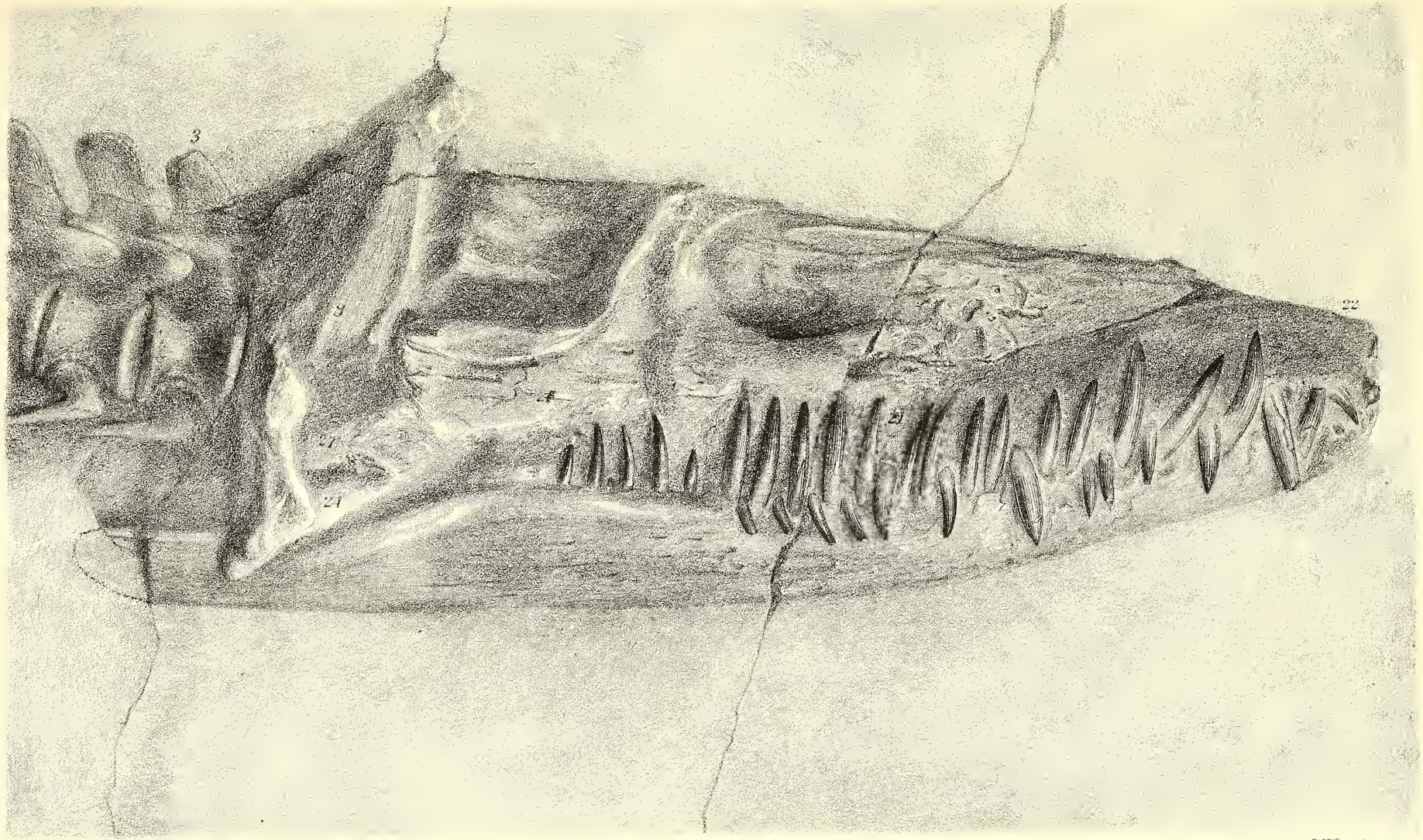
PLESIOSAURUS DOLICHODEIRUS.

TAB. II.

Plesiosaurus dolichodeirus.

Side view of the skull of the skeleton in Tab. I, nat. size.

From the Lower Lias of Lyme Regis. In the British Museum.



J. Dinkel, del. et lith

W. West, imp

PLESIOSAURUS DOLICHODEIRUS.

T. II.

TAB. III.

Plesiosaurus dolichodeirus, nat. size.

Fig.

1. Skull and seven cervical vertebræ.
2. Dentary elements of lower jaw.
3. Front view of premaxillaries and interlocked fore teeth of both jaws, those of the lower in outline.
4. Middle cervical vertebra, side view.
5. Ib., under view.
6. Ib., front view.

From the Lower Lias of Charmouth. In the British Museum.

J.Dinkel, del et lith.

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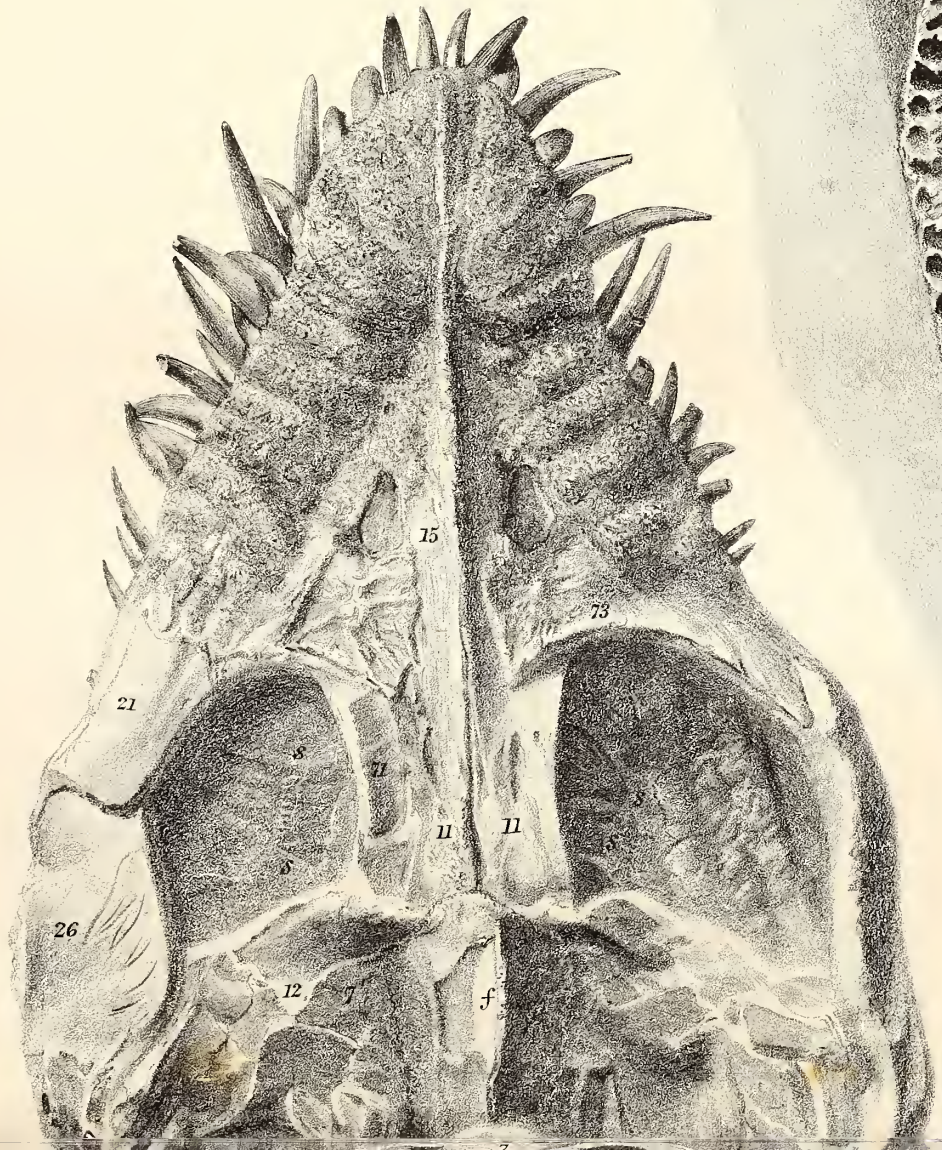

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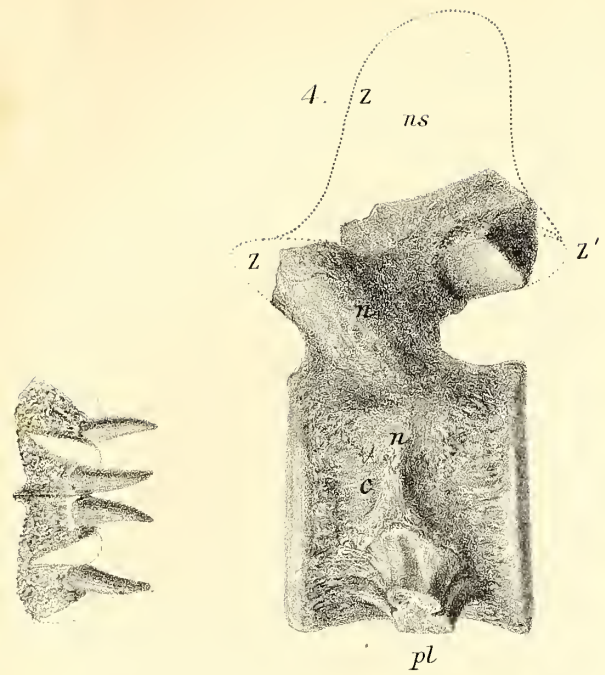
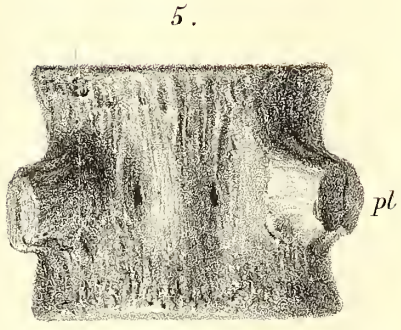
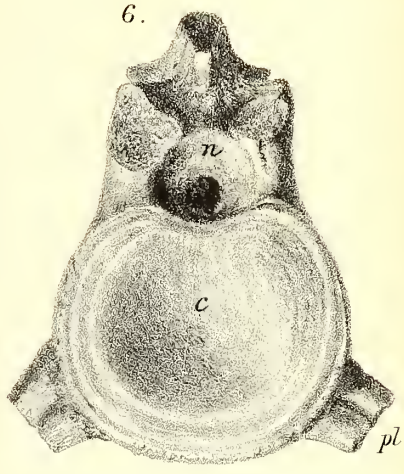
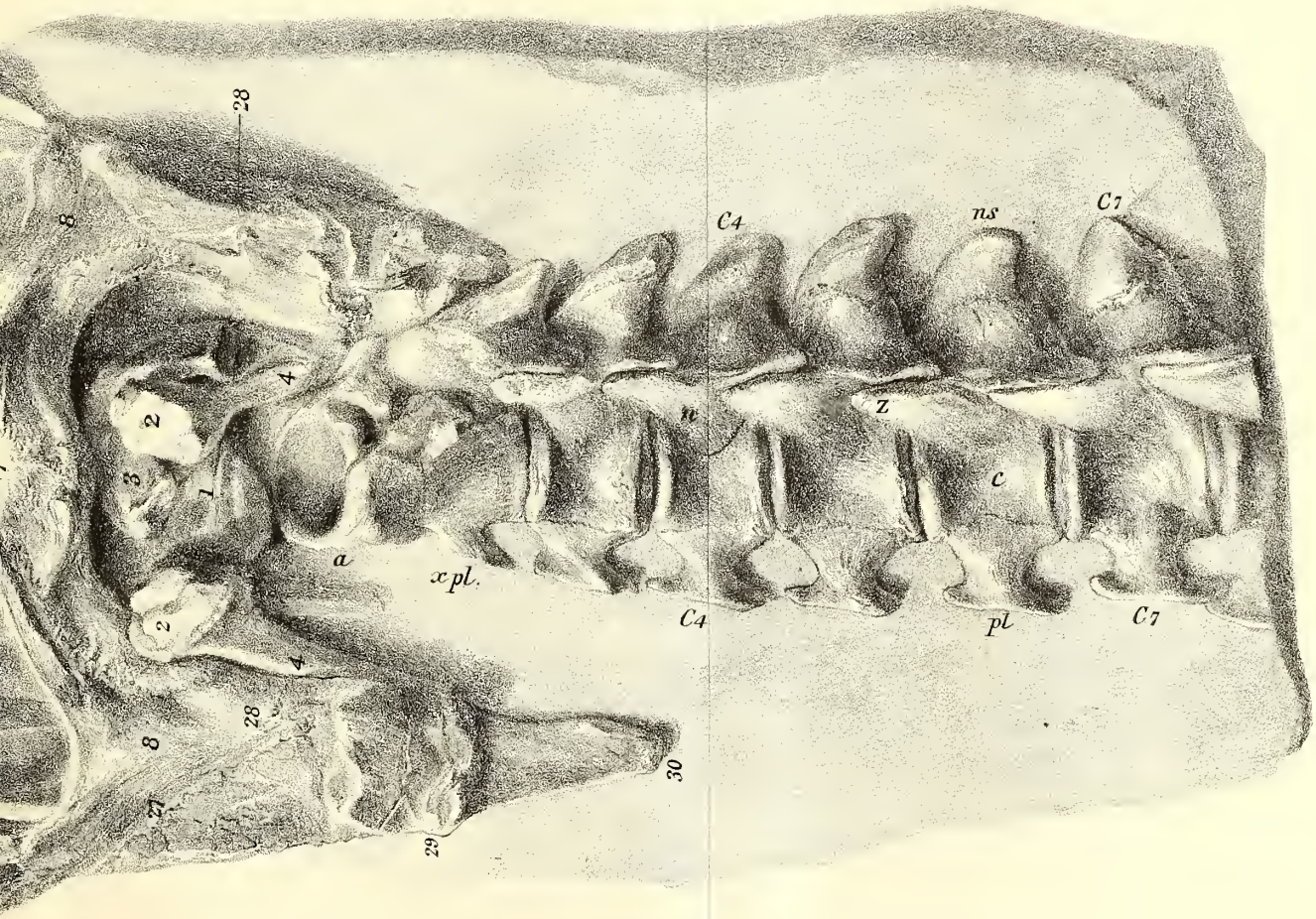
PLESIOSAURUS



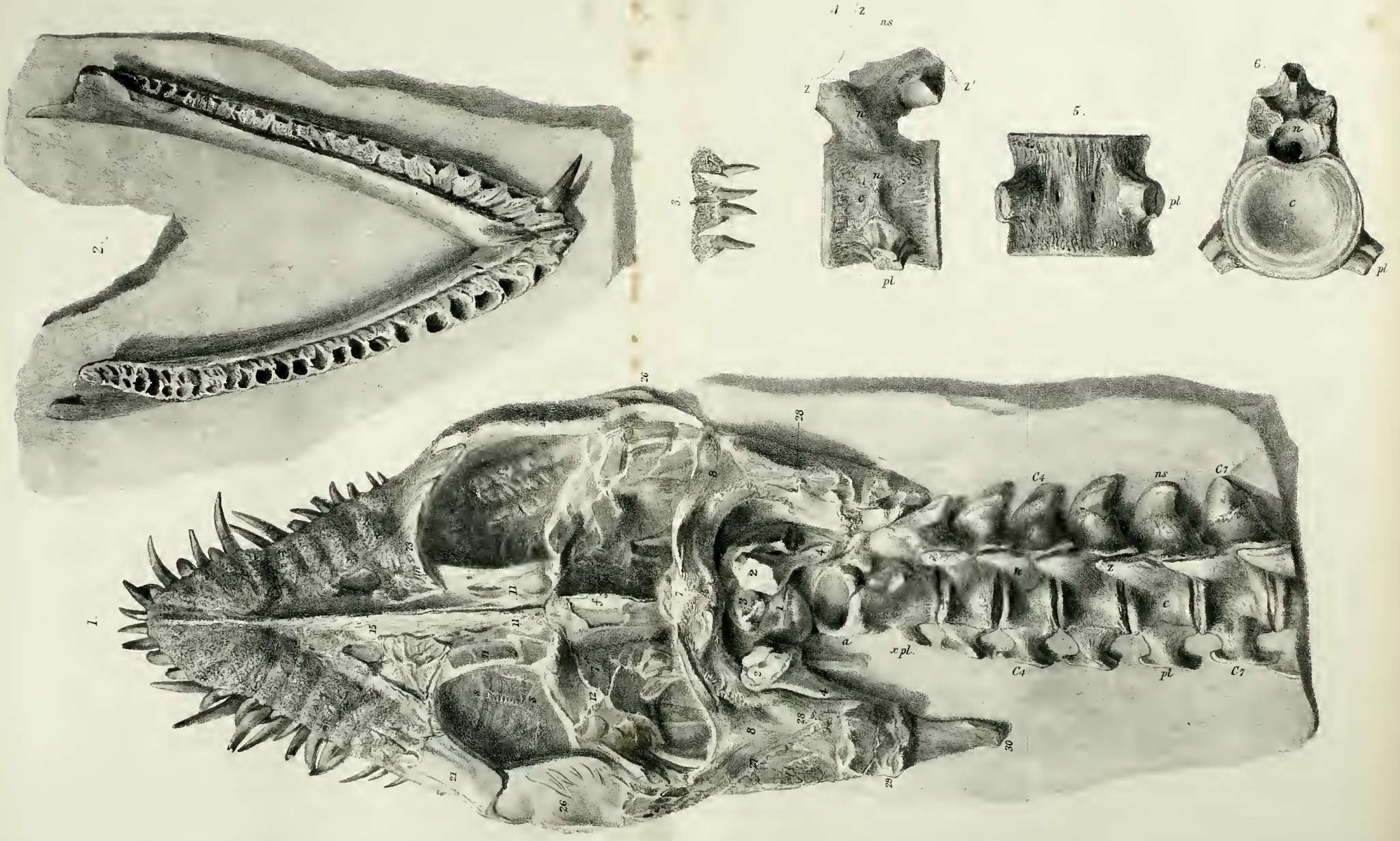






W.West, imp.

DOLICHODEIRUS, Cb.



J.Dinkel, del et lith.

W.West, imp.

PLESIOSAURUS DOLICHODEIRUS, Cb.

TAB. IV.

Plesiosaurus dolichodeirus, nat. size.

Fig.

1. Dorsal vertebra, side view.
2. Ib., back view.
3. Tenth caudal vertebra, side view.
4. Ib., under view of centrum.
5. Ib., back view.
6. Twelfth caudal vertebra, side view.
7. Ib., under view of centrum.
8. Ib., back view.
9. Thirtieth caudal vertebra, back view.

From the Lower Lias of Charmouth. In the British Museum.

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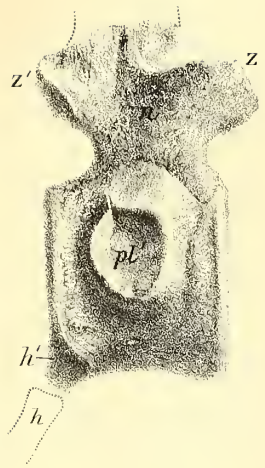

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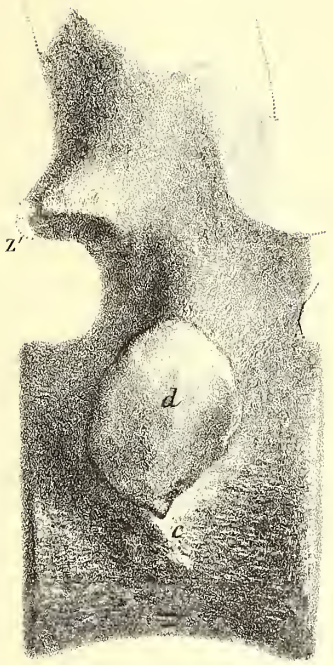

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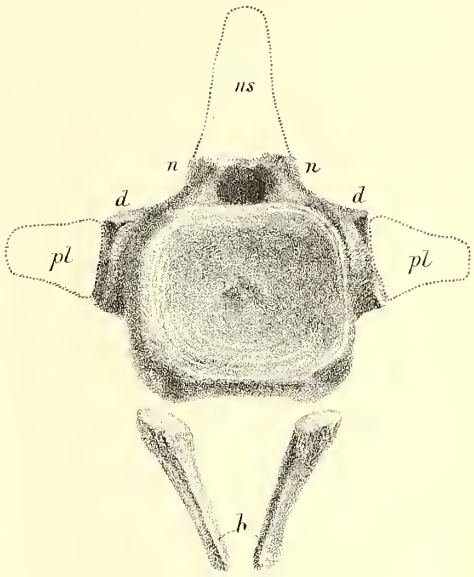

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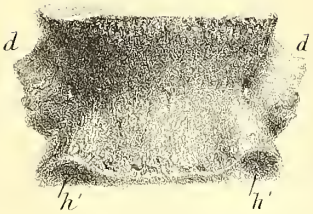

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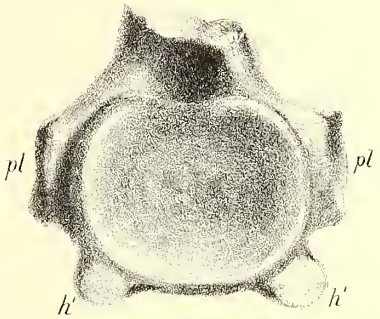

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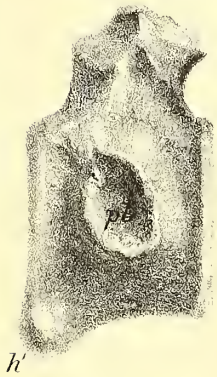

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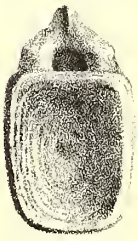

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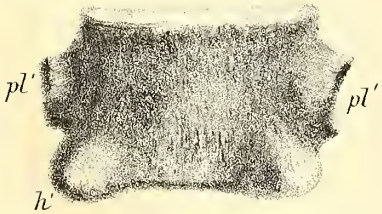


Dinkel, del. et lith.

W. West, imp.

PLESIOSAURUS DOLICHODEIRUS.

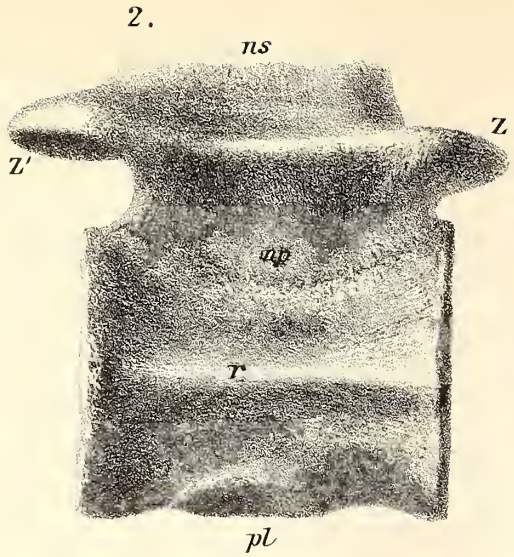
TAB. V.

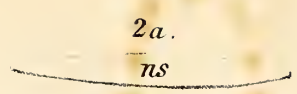
Plesiosaurus homalospondylus.

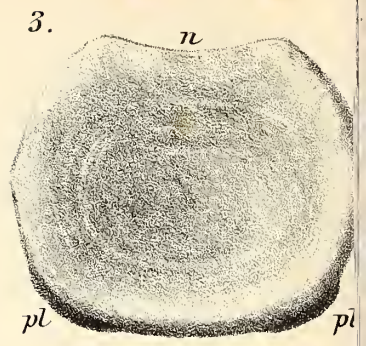
Fig.

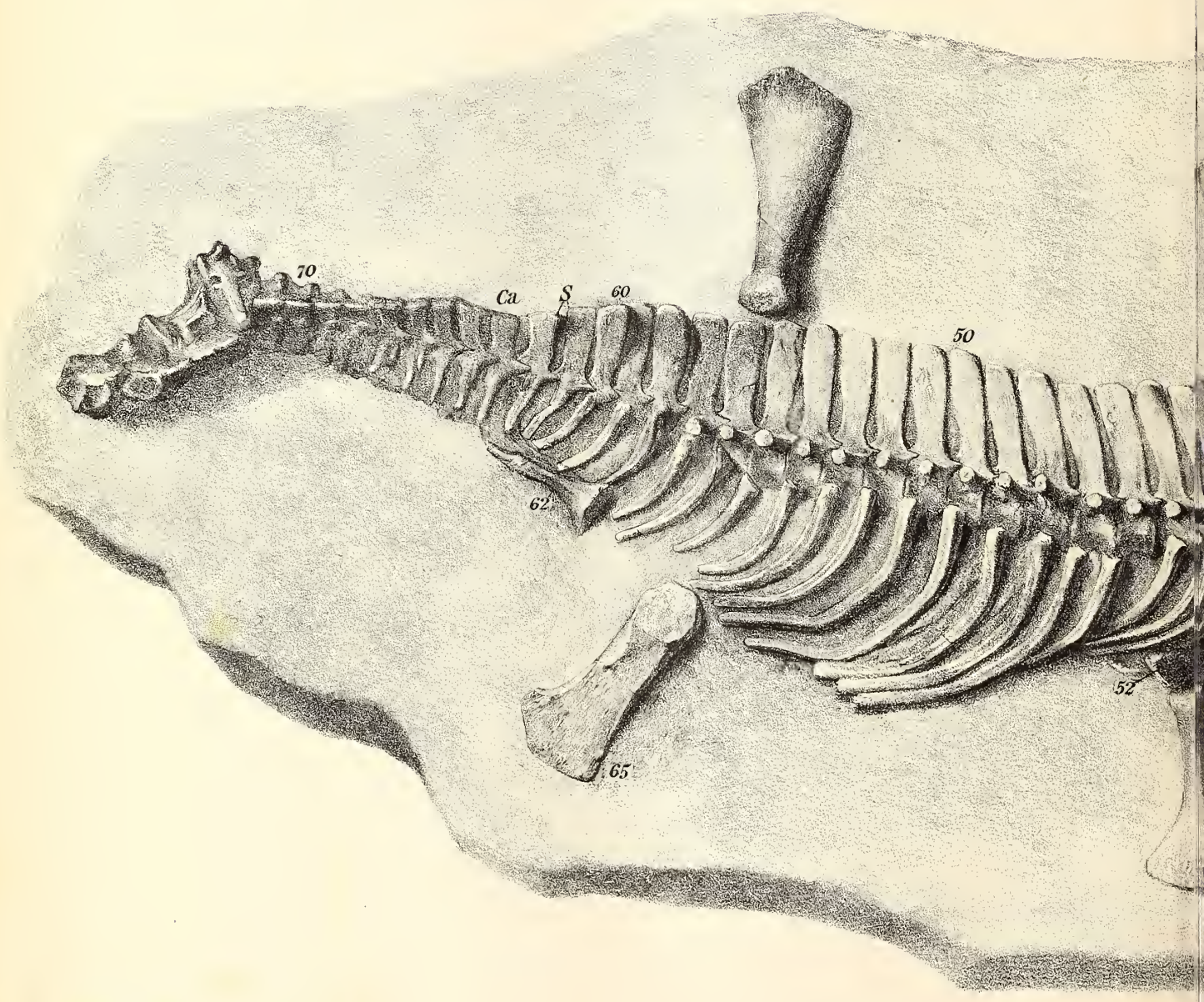
1. Skeleton, about 1-10th nat. size.
2. Thirteenth cervical vertebra of ditto, side view., nat. size.
2A. Ib., section of neural spine, ib.
3. Ib., posterior surface of centrum, ib.
4. Fourteenth cervical vertebra, under view, ib.
5. Centrum of third cervical vertebra, side view, ib.
6. Ib., posterior surface, ib.
7. Centrum of eighth cervical vertebra, under view, ib.

From the Upper Alum Shale, Lias, Whitby. In the British Museum.









J.Dinkel, del. et lith.

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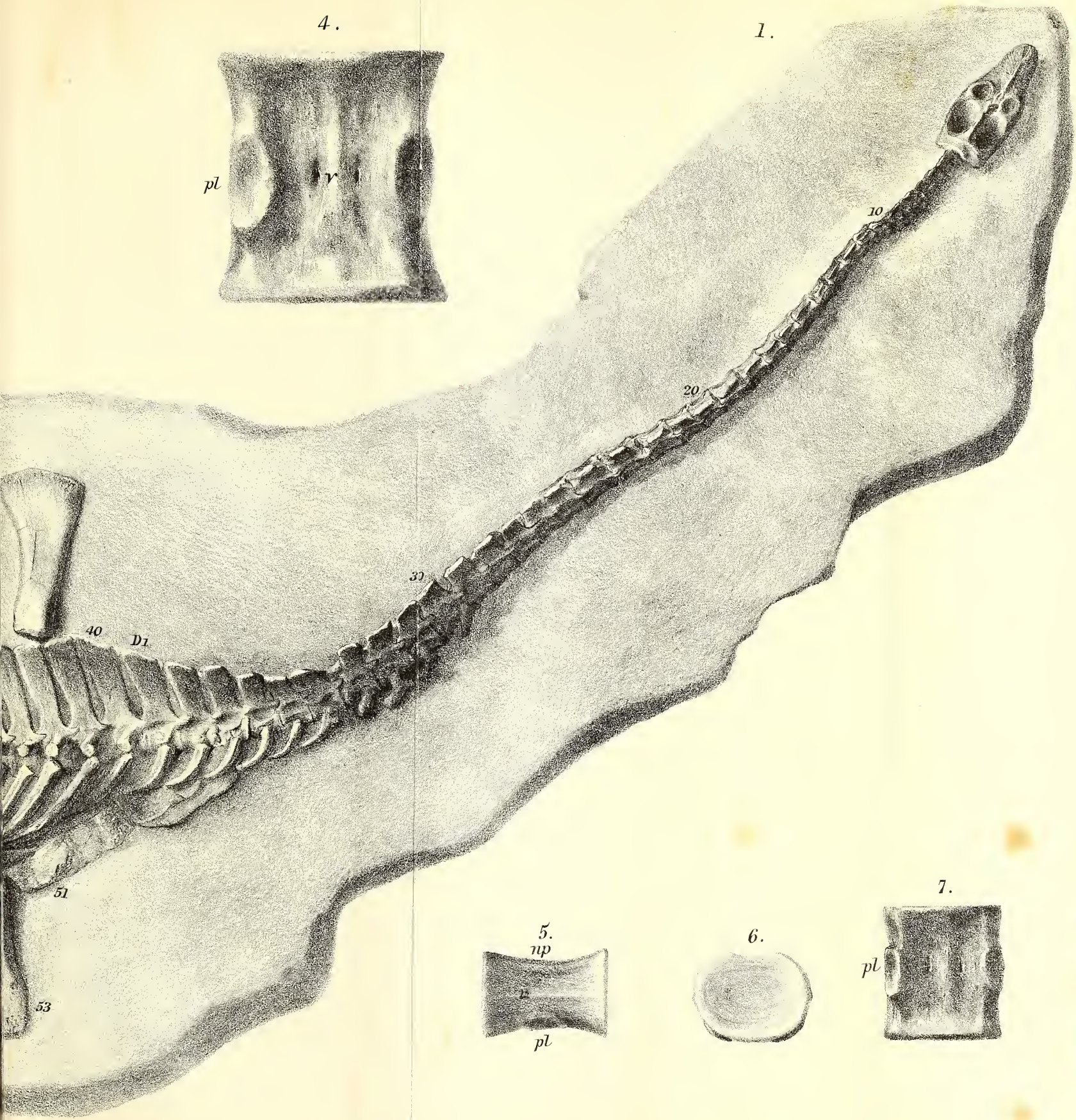
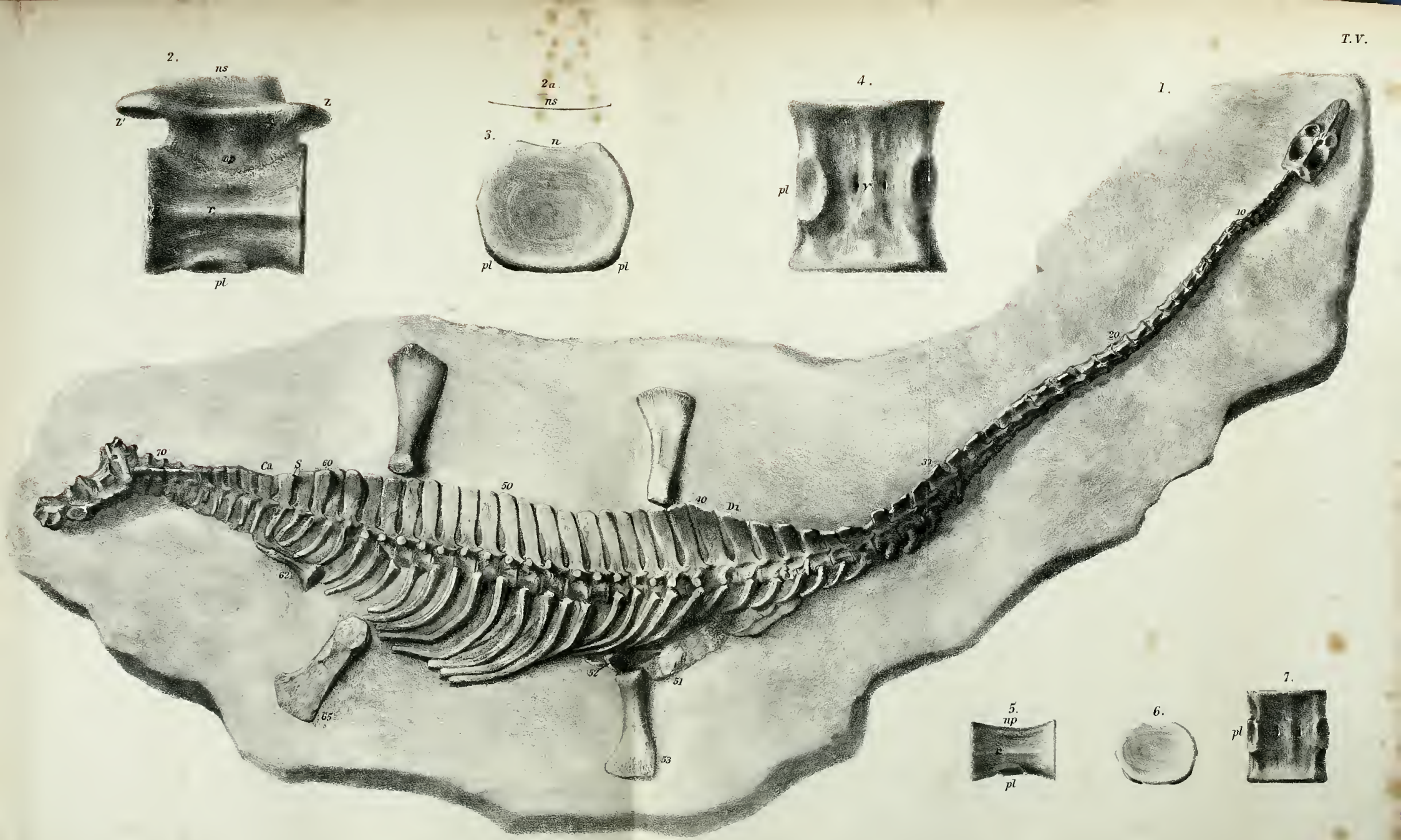


W.West,imp.

RUS HOMALOSPONDYLUS.



J.Dinkel, del et lith

W.West, imp.

0 1 2 feet.

PLESIOSAURUS HOMALOSPONDYLUS.

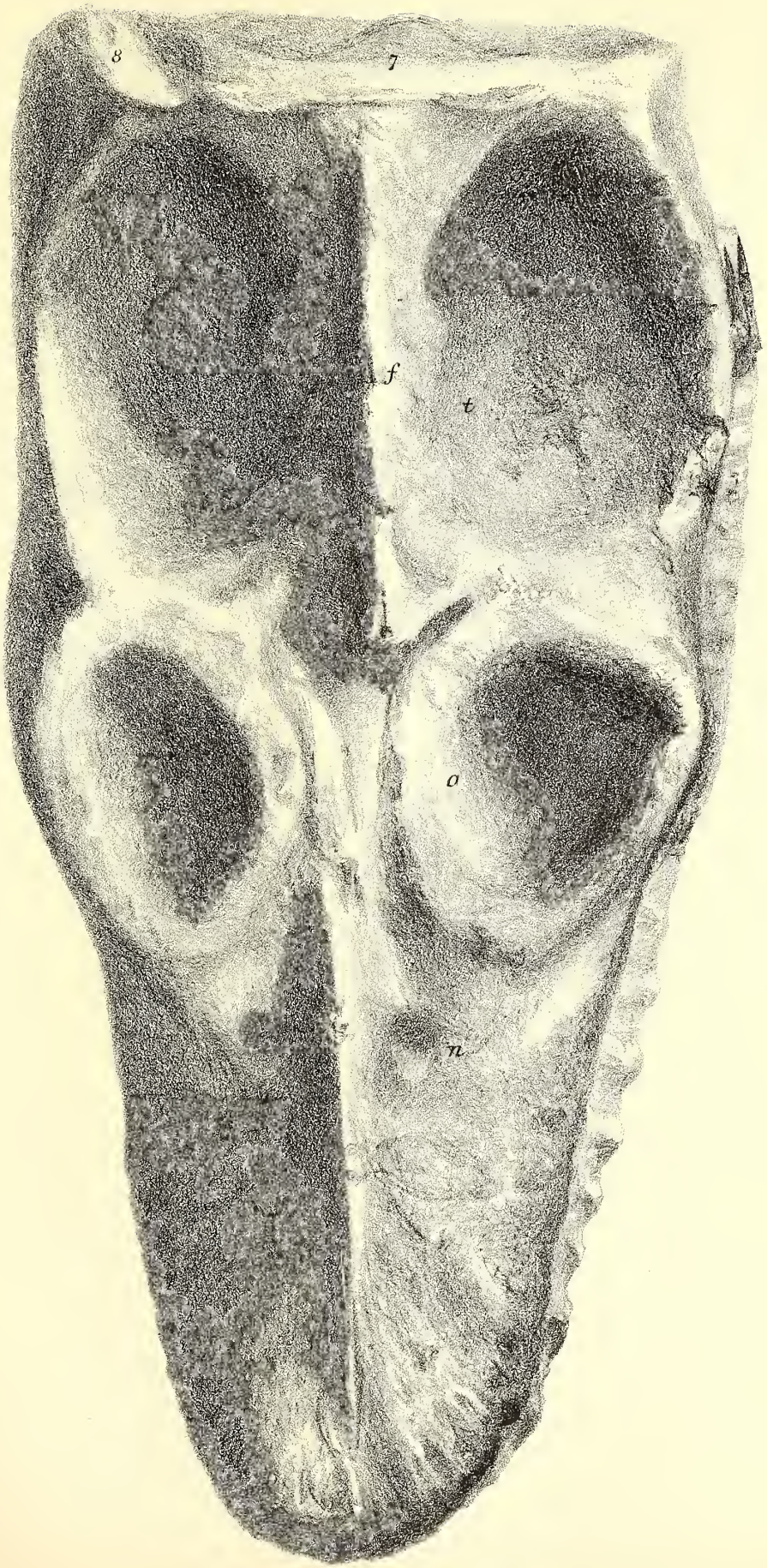
TAB. VI.

Plesiosaurus homalospondylus.

Upper view of the skull of the skeleton, Tab. V, nat. size.

From the Upper Alum Shale, Lias, Whitby. In the British Museum.

J. Dinkel, del. et lith.



PLESIOSAURUS HOMALOSPONDYLUS.

W. West imp.

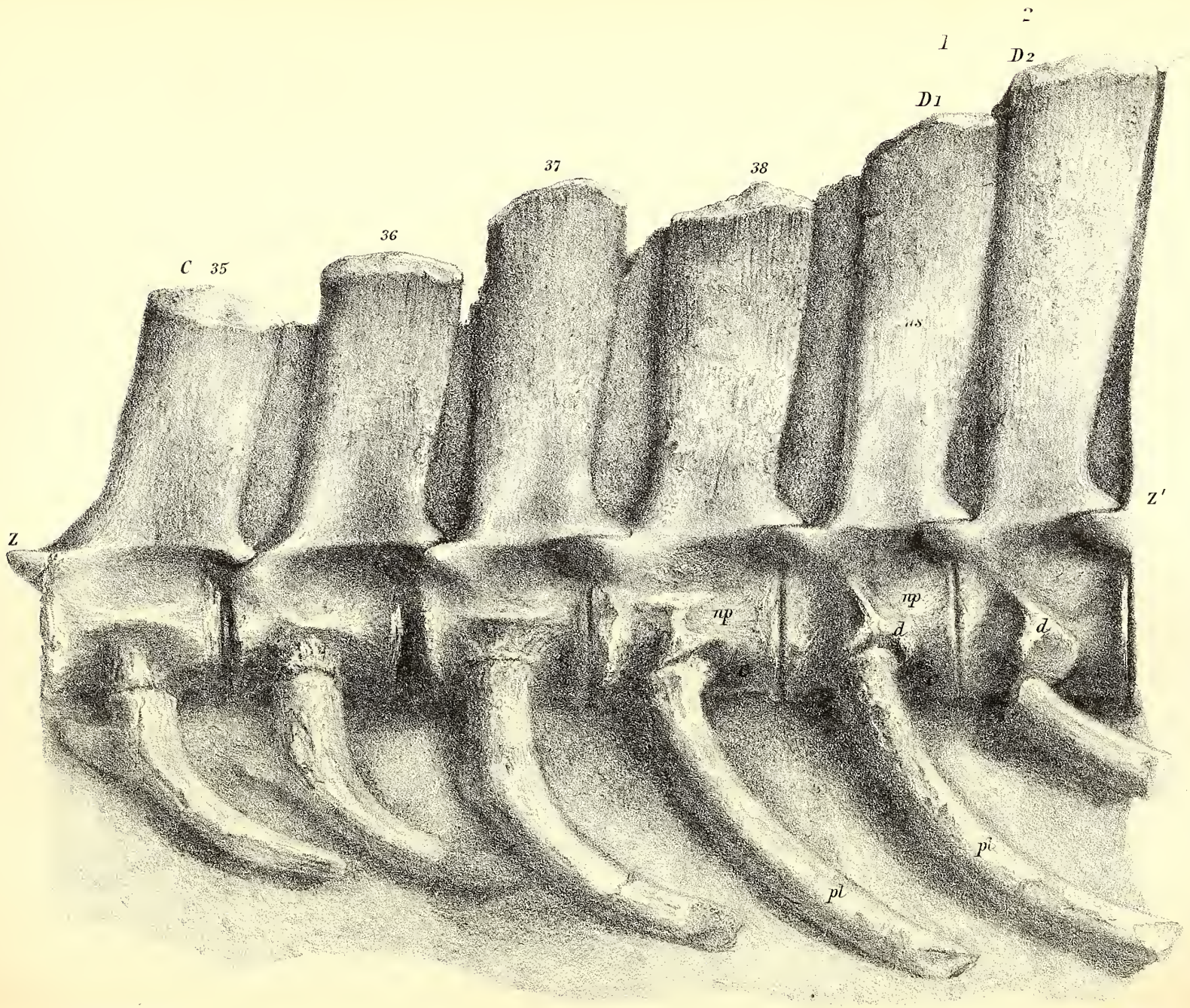
TAB. VII.

Plesiosaurus homalospondylus, half nat. size.

Four last cervical and first two dorsal vertebræ of the skeleton, Tab. V, half nat. size.

From the Upper Alum Shale, Lias, Whitby. In the British Museum.

T. VII.



J.Dinkel, del. et lith.

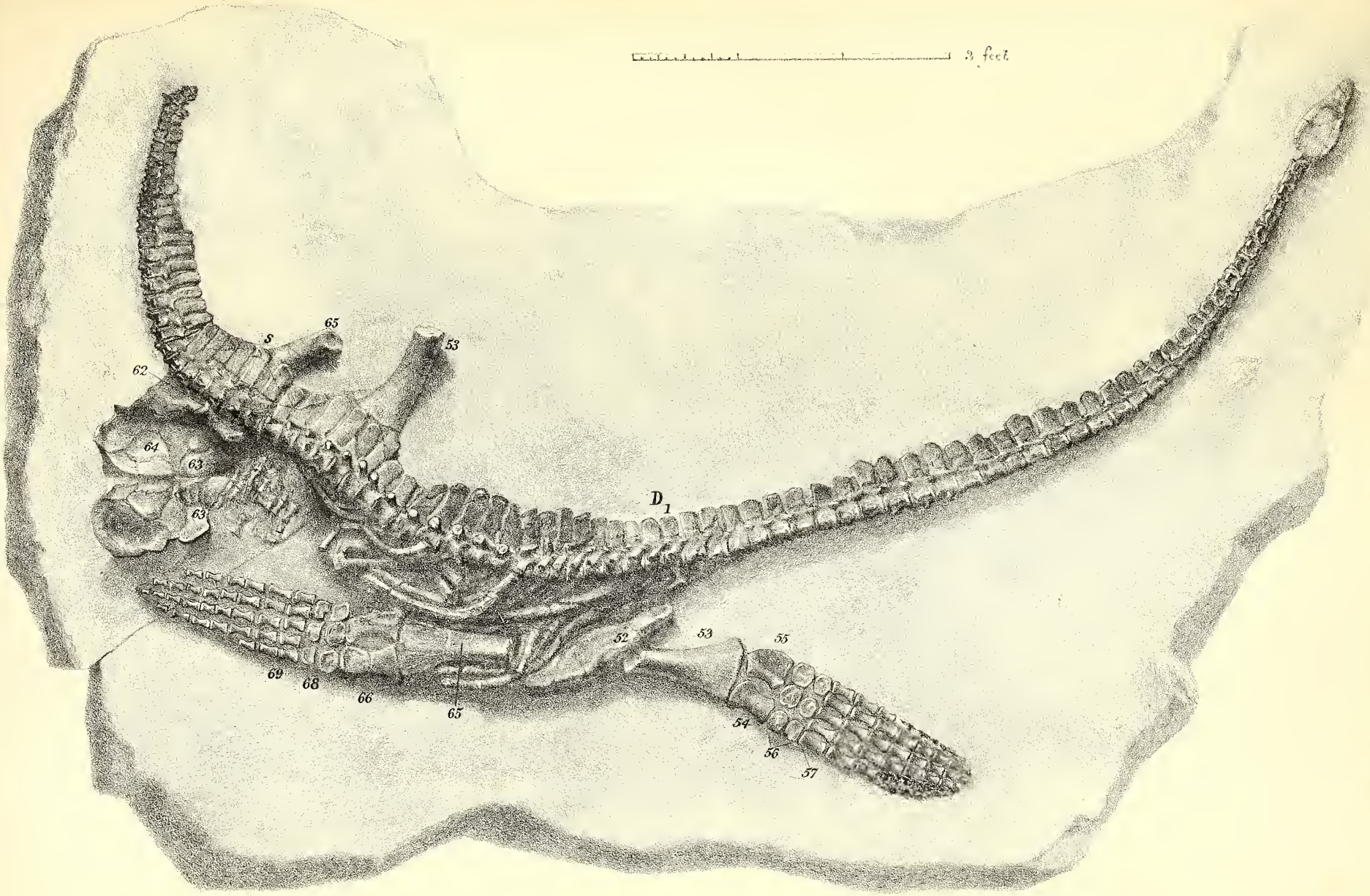
W.West, imp.

PLESIOSAURUS HOMALOSPONDYLUS.

TAB. VIII.

Plesiosaurus homalospondylus (reduced to scale).

From the Upper Alum Shale, Whitby. In the Museum of the Philosophical Society, York.



PLESIOSAURUS HOMALOSPONDYLUS

T. VIII.

4.

W.West, imp.

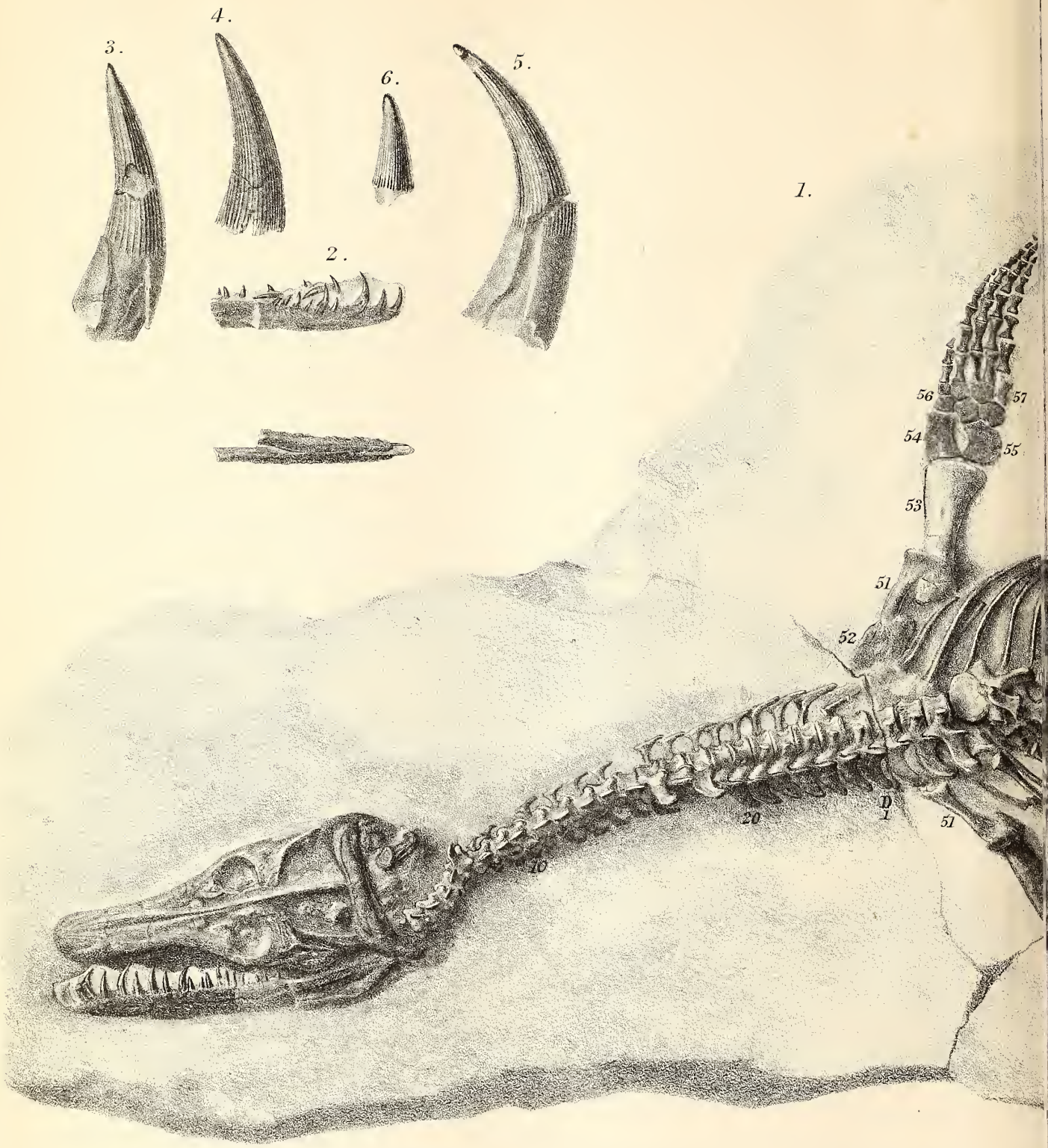
TAB. IX.

Plesiosaurus rostratus.

Fig.

1. Skeleton (reduced to scale).
2. Right dentary bone and teeth, external and internal surfaces of lower jaw, ib.
3. Crown of the tooth of left dentary, nat. size.
4. Crown of the tooth of left dentary, nat. size.
5. Crown of fourth tooth of right dentary, nat. size.
6. Crown of hind tooth of left dentary, nat. size.
7. Crown of sixth tooth of right dentary, nat. size.
8. Crown of hind tooth of right dentary, nat. size.
9. Crown of ninth tooth of left dentary, nat. size.

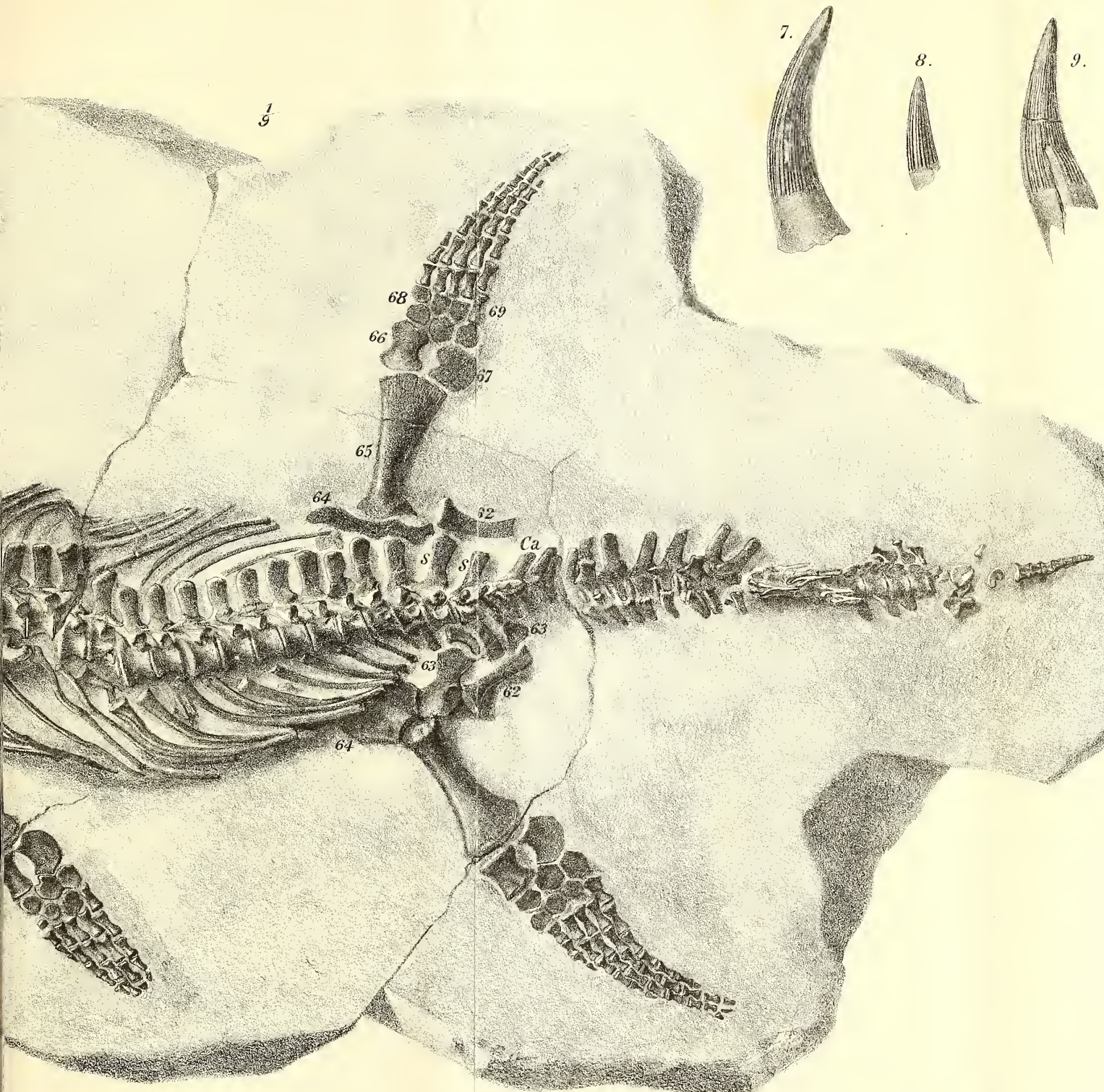
From the Lower Lias of Charmouth. In the British Museum.



Scale.

0 1 2 feet.

J. Dinkel, del. et lith.



W. West, imp.

AURUS ROSTRATUS.

J. Dinkel, del. et lith.

W. West, imp.

PLESIOSAURUS ROSTRATUS.

TAB. X.

Plesiosaurus rostratus, nat. size.

Fig.

1. Side view of the fifteenth cervical vertebra.

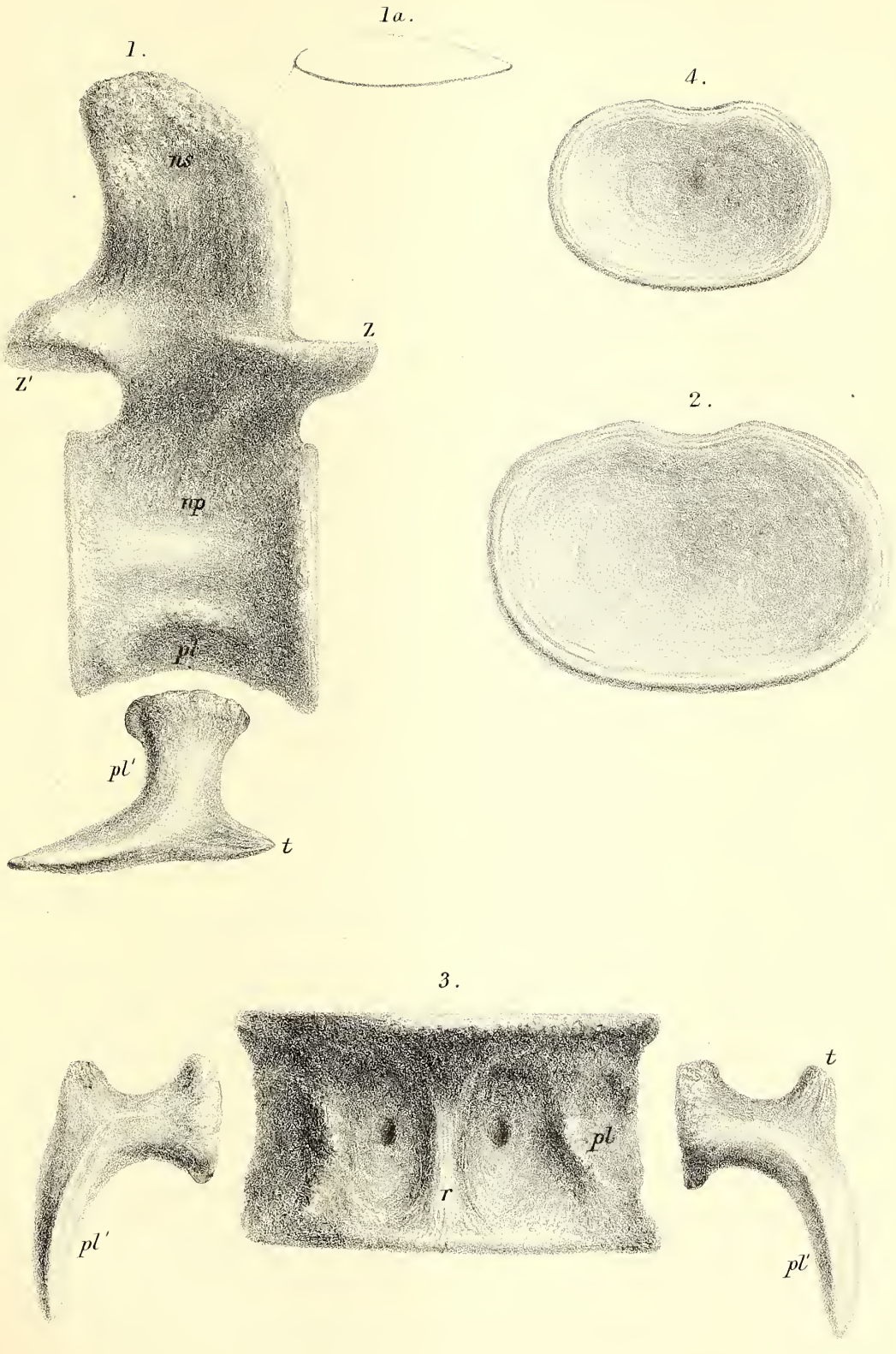
1A. Section of neural spine.

2. Posterior articular surface of centrum of cervical vertebra.

3. Inferior surface of centrum and pleurapophyses.

4. Posterior articular surface of centrum of cervical vertebra.

From the Lower Lias of Charmouth. In the British Museum.



J.Dinkel, del. et lith.

W.West, imp.

TAB. XI.

Plesiosaurus rostratus, nat. size.

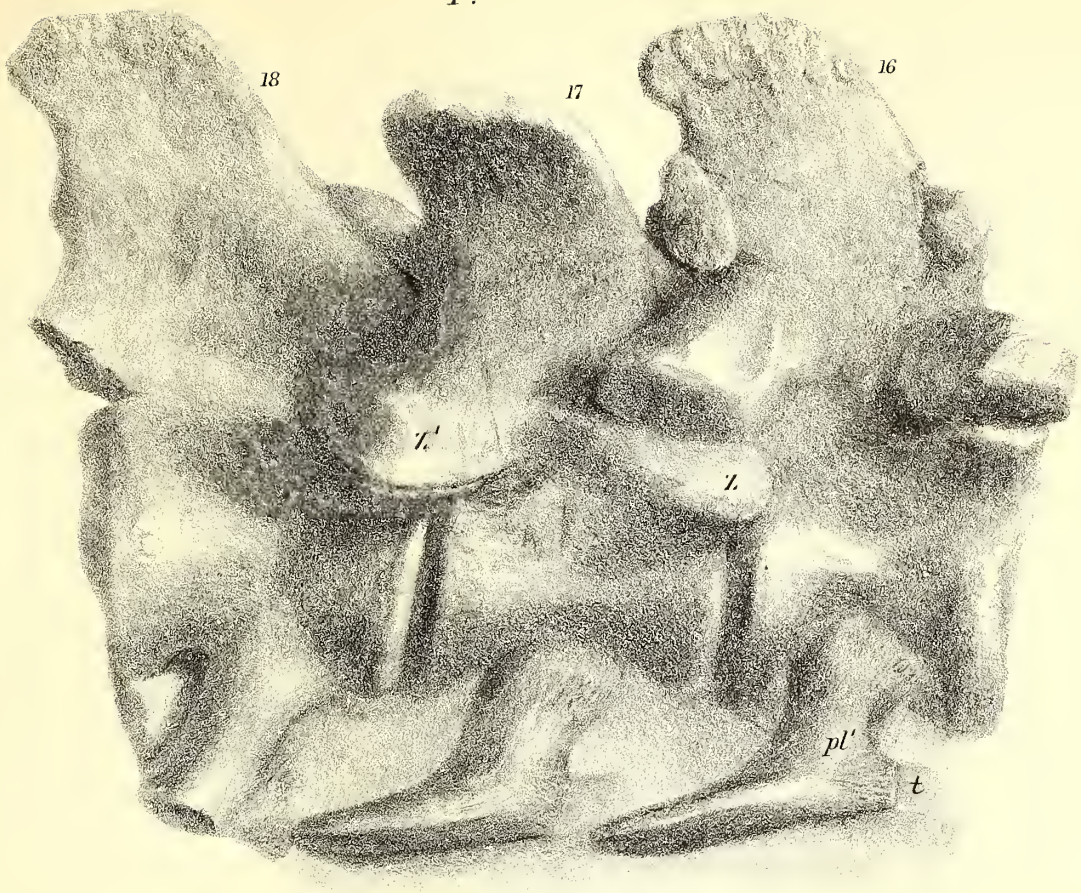
Fig.

1. Side view of the sixteenth, seventeenth, and eighteenth cervical vertebræ, partially dislocated.

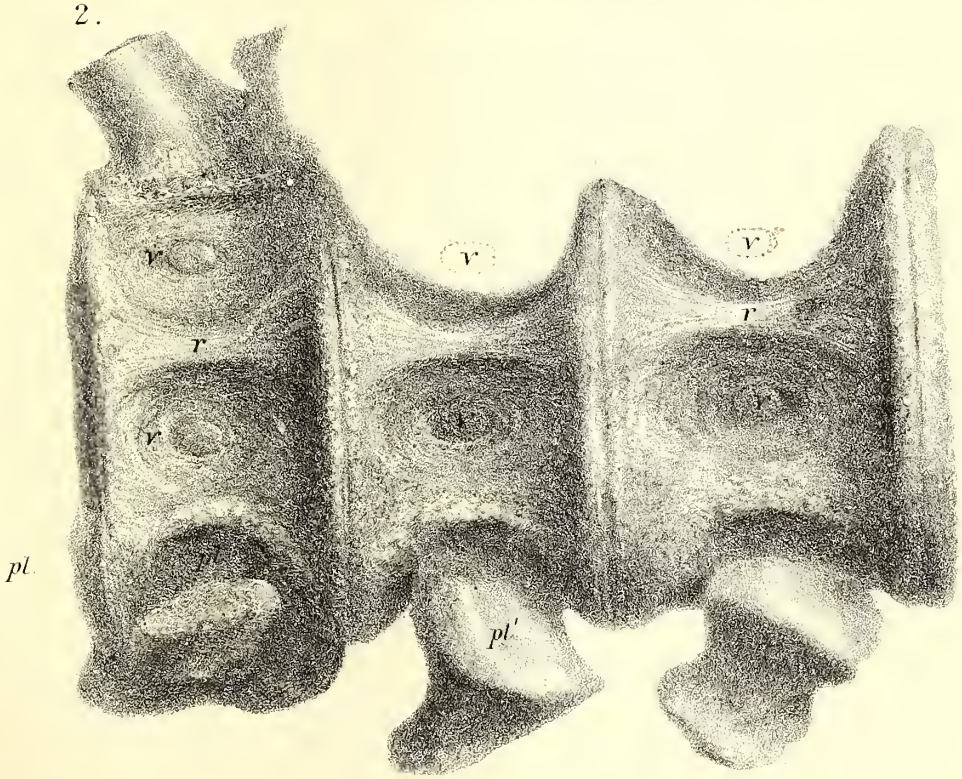
2. Under view of ditto.

From the Lower Lias of Charmouth. In the British Museum.

1.



2.



J.Dinkel, del. et lith.

W West, imp

PLESIOSAURUS ROSTRATUS.

TAB. XII.

Plesiosaurus rostratus, nat. size.

Side view of the five last cervical and first dorsal vertebræ.

From the Lower Lias of Charmouth. In the British Museum.

J.Dinkel, del. et lith.

W.West, imp.

PLESIOSAURUS ROSTRATUS.

T.XIII.

TAB. XIII.

Plesiosaurus rostratus, nat. size.

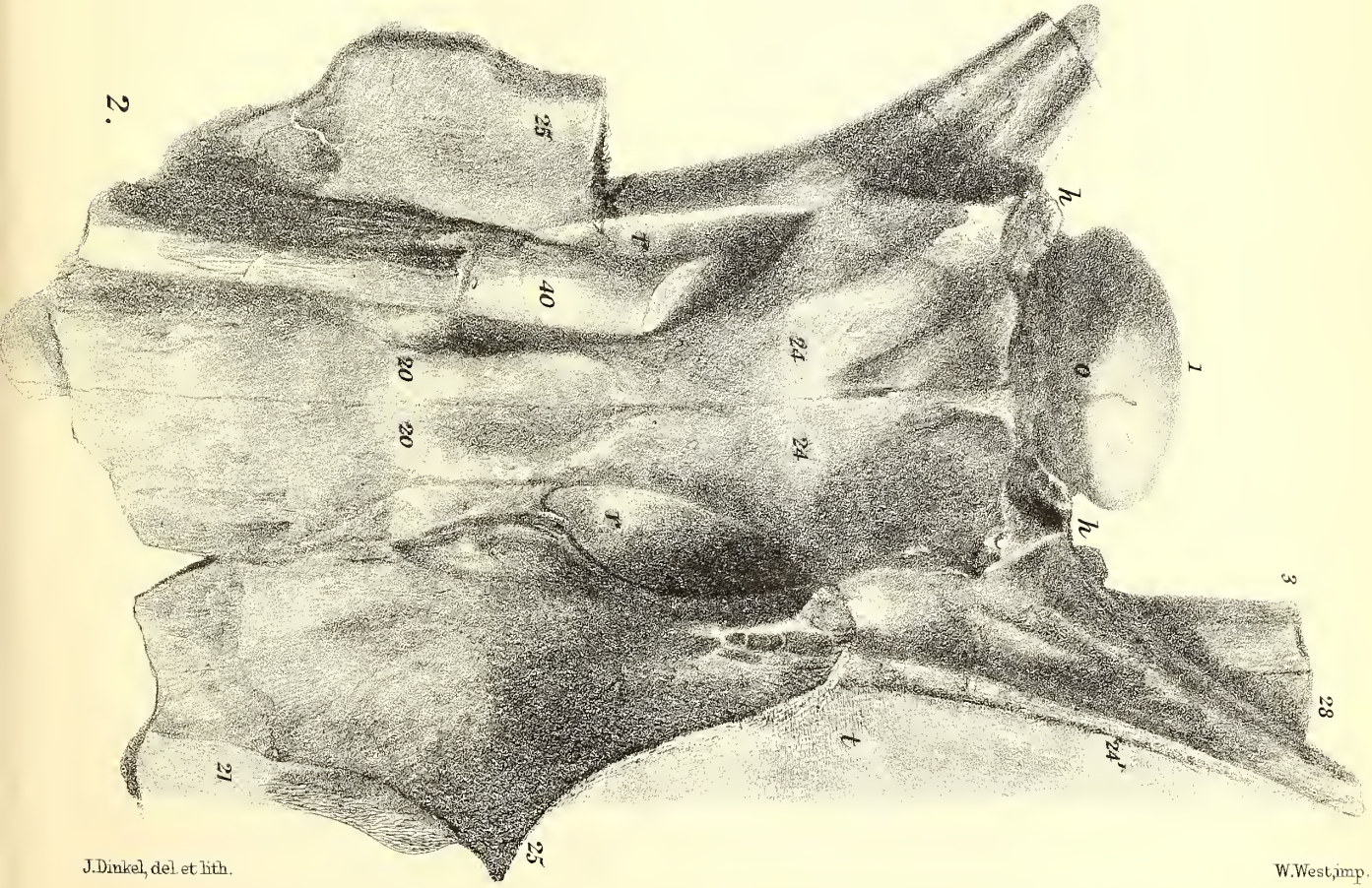
Fig.

1. Upper view of basal portion of skull.
2. Under view of ditto.

From the Lower Lias of Charmouth. In the British Museum.

1.

2.



J.Dinkel, del. et lith.

W.West, imp.

PLESIOSAURUS ROSTRATUS.

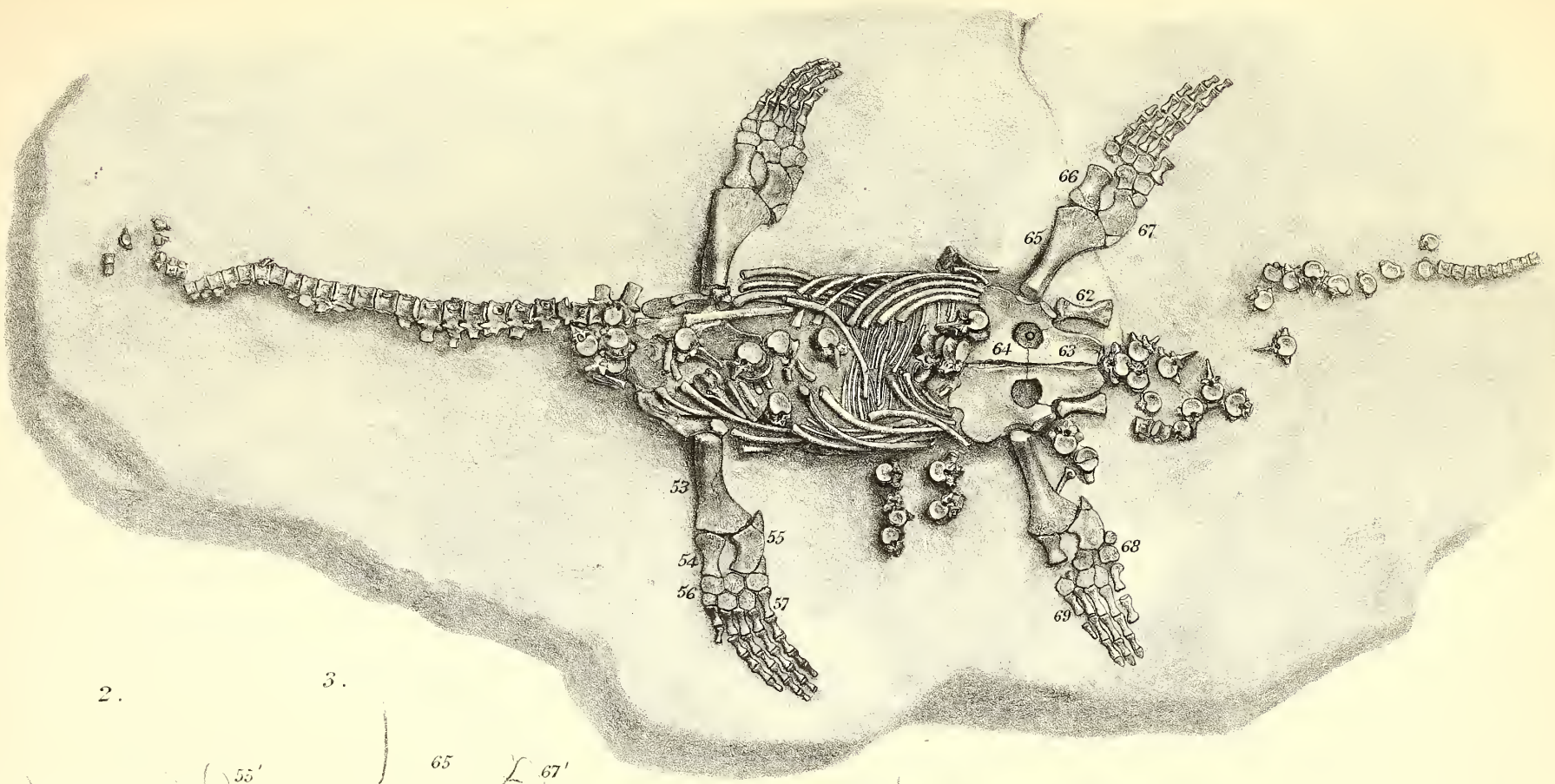
TAB. XIV.

Fig.

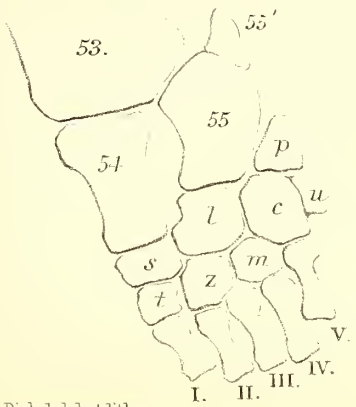
1. Skeleton of *Plesiosaurus rugosus,* 1-14th nat. size.
2. Bones of forearm, carpus, and metacarpus, of ditto; in outline, 1-6th nat. size.
3. Bones of leg, tarsus, and metatarsus, of ditto; in outline, 1-6th nat. size.
4. Bones of forearm, carpus, and metacarpus, of *Plesiosaurus macrocephalus;* in outline, 1-6th nat. size.
5. Bones of forearm, carpus, and metacarpus, of *Plesiosaurus dolichodeirus;* in outline, 1-6th nat. size.
6. Bones of forearm, carpus, and metacarpus, of *Plesiosaurus Hawkinsii;* in outline, 1-6th nat. size.

The skeleton of the *Plesiosaurus rugosus* is from the Lower Lias of Leicestershire. In the British Museum.

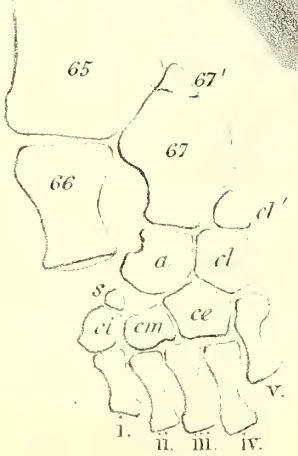
1.



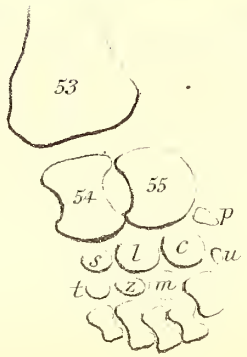
2.



3.

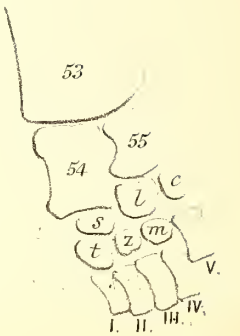


4.



5.

6.



J. Dinkel, del. et lith

W. West, imp.

PLESIOSAURUS RUGOSUS

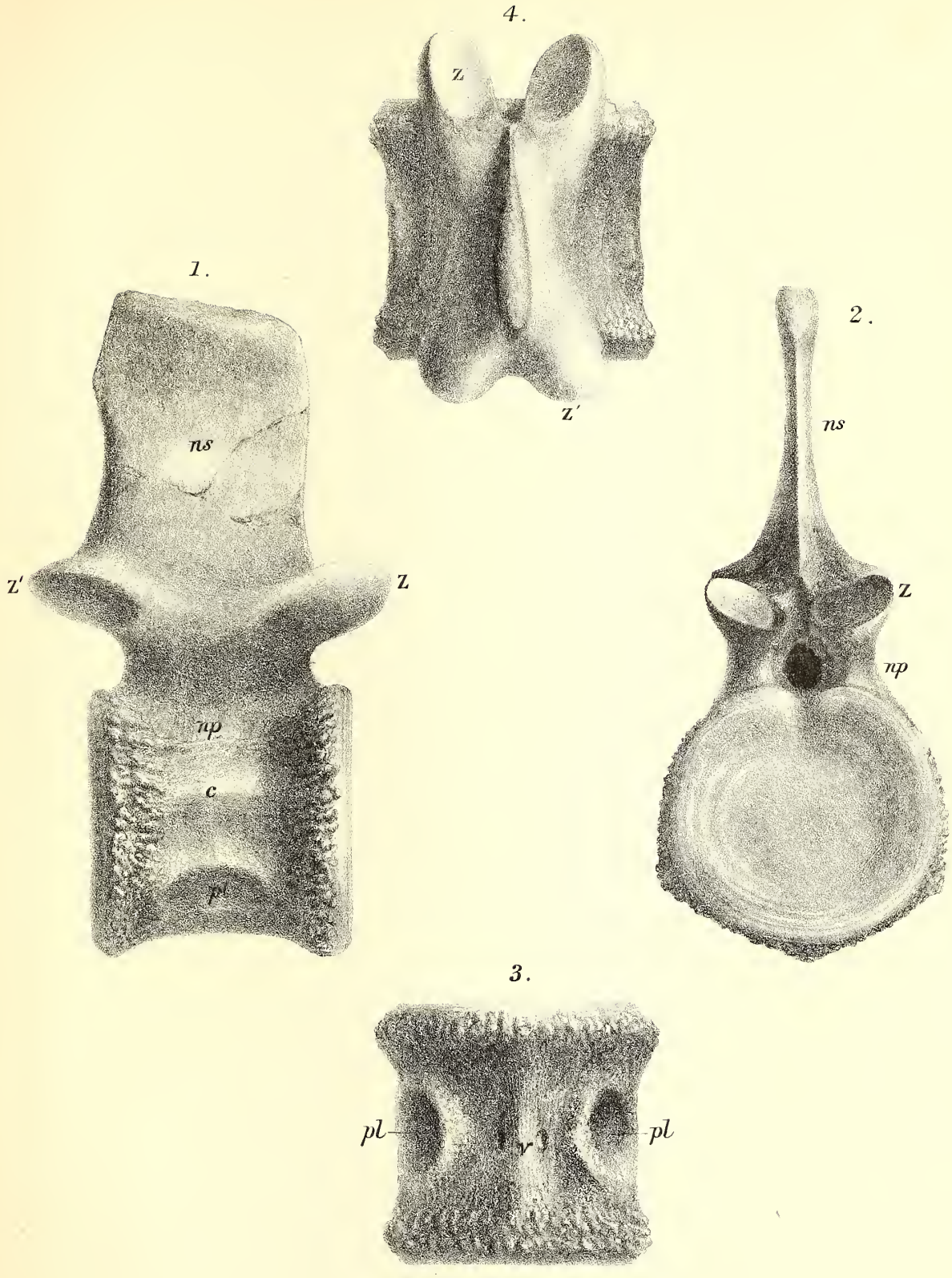
TAB. XV.

Plesiosaurus rugosus, nat. size.

Fig.

1. Side view of the fifteenth cervical vertebra.
2. Front view of ditto.
3. Under view of ditto.
4. Upper view of ditto.

From the Lower Lias of Leicestershire. In the British Museum.



J.Dinkel, del. et lith.

W.West, imp.

PLESIOSAURUS RUGOSUS.

TAB. XVI.

Plesiosaurus Hawkinsii, nat. size.

Fig.

1. Oblique side view of skull.
2. Under view of skull.

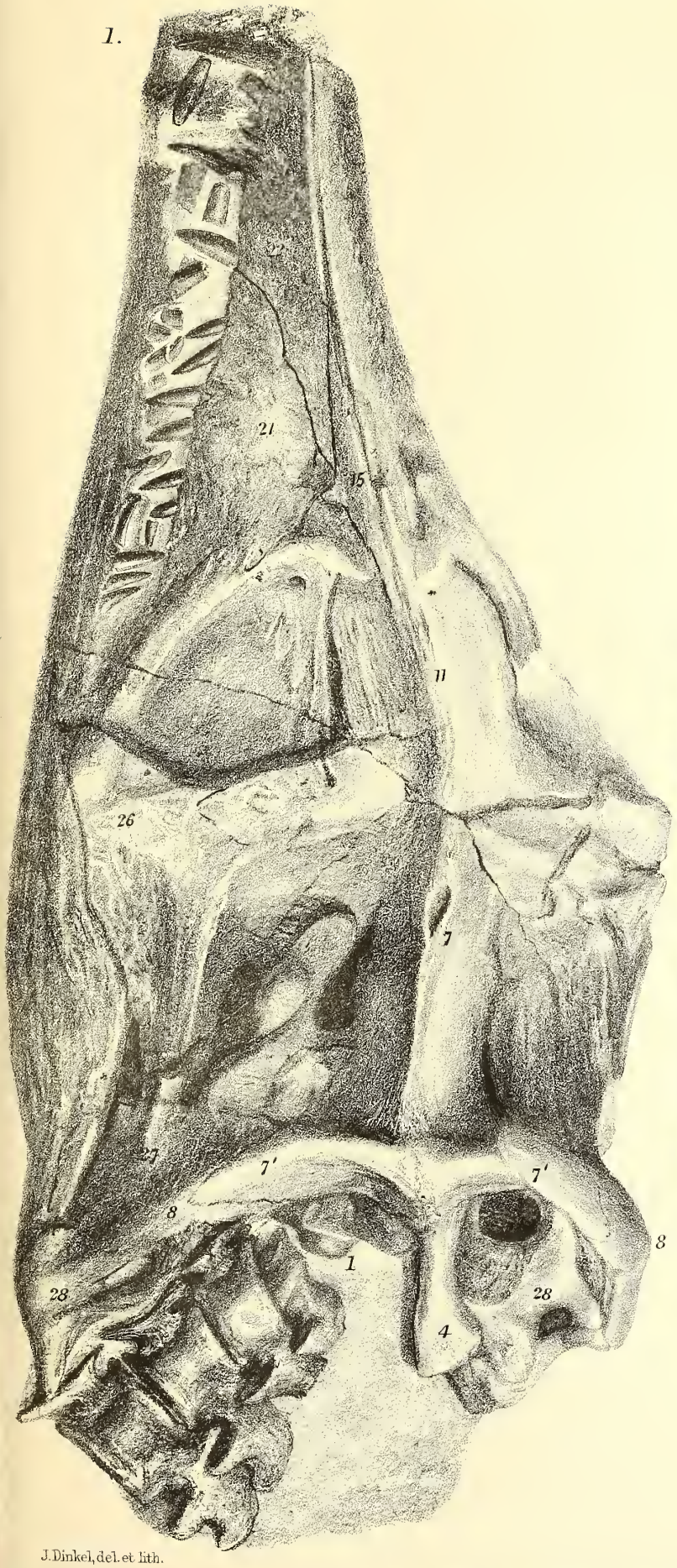
In comparison with the skull of *Plesiosaurus dolichodeirus*, Tabs. II and III, these figures exemplify the specific distinction of *Ples. Hawkinsii* in the greater longitudinal extent of the temporal fossæ, and in the greater relative length and slenderness of the muzzle or facial part of the skull, the sides of which converge at a more acute angle and are more concave. The symphysis of the mandible is longer in *Pl. Hawkinsii*. The teeth in both jaws are relatively larger and longer in *Plesiosaurus dolichodeirus*. As compared with *Plesiosaurus rostratus*, Tabs. IX and XIII, the facial part of the skull is relatively shorter in *Plesiosaurus Hawkinsii*; the pterygoids do not extend quite so far back; the "palatonares," Tab. XVI, fig. 2, *r*, *r*, are smaller, with more rounded ends of the ellipse.

The following bones are indicated by the figures:

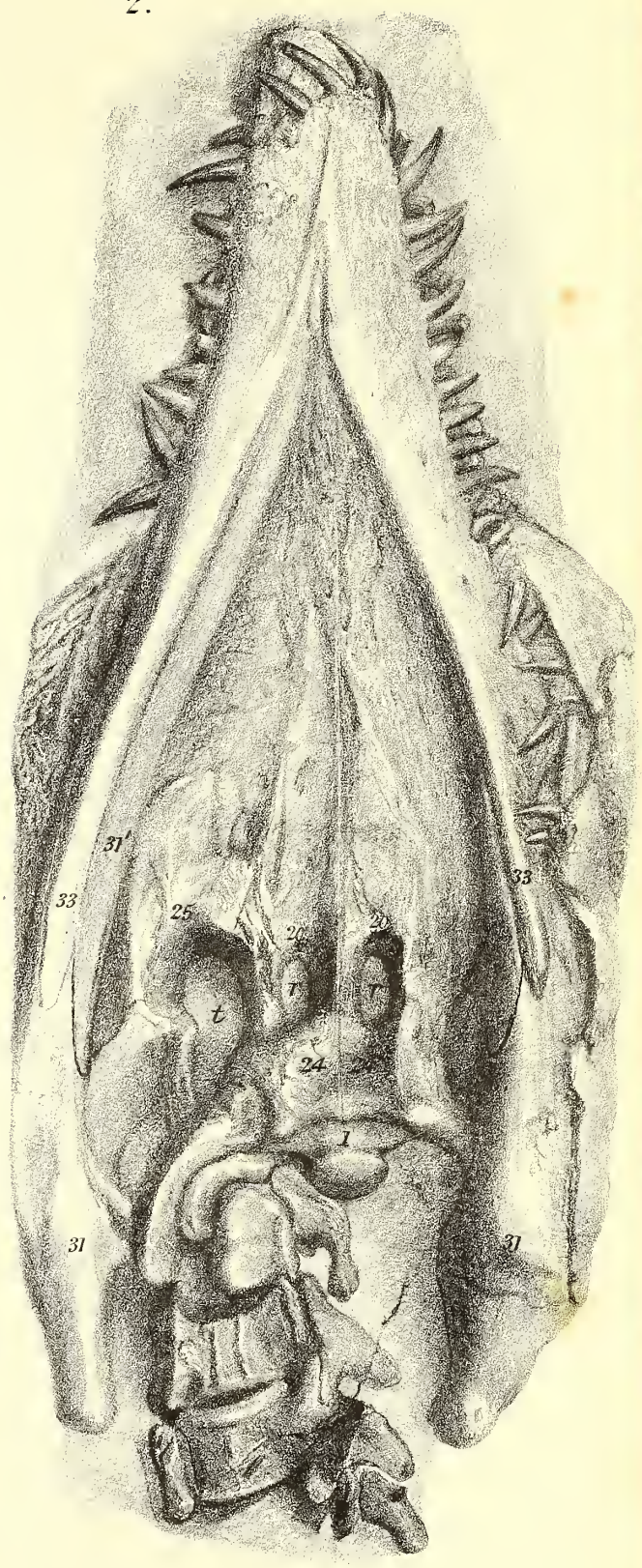
1. Basi-occipital.
2. Par-occipital.
7. Parietal (near the "foramen parietale").
7'. Ib., "supra-mastoid process."
8. Mastoid.
11. Frontal.
15. Nasal (above the external nostril).
20. Palatine.
24. Pterygoid.
25. Ecto-pterygoid.
26. Malar.
27. Squamosal.
28. Tympanic.
31. Angular.
31'. Splenial.
33. Dentary.

The skulls here figured are from the Lias of Street, Somersetshire. In the British Museum.

1.



2.



J.Dinkel, del. et lith.

W.West, imp.

PLESIOSAURUS — HAWKINSII

THE

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MDCCCLXX.

MONOGRAPH

OF

THE FOSSIL REPTILIA

OF THE

LIASSIC FORMATIONS.

BY

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FOREIGN ASSOCIATE OF THE INSTITUTE OF FRANCE,
ETC. ETC.

PART SECOND.

PTEROSAURIA.

Pages 41—81; Plates XVII—XX.

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MONOGRAPH

OF

THE FOSSIL REPTILIA

OF THE

LIASSIC FORMATIONS.

ORDER—PTEROSAURIA, *Owen.*

Genus—DIMORPHODON, *Owen.*

Species—DIMORPHODON MACRONYX, *Buckland.*

REMAINS of volant Reptiles (*Pterosauria*) were later recognised, and, save in the instance about to be recorded, in a more fragmentary or scattered condition, in England than in Continental localities.

A single bone or tooth gives value to a slab of Stonesfield Slate, and the evidence of a Pterodactyle rarely goes beyond such specimen in that Oolitic deposit. A jaw with teeth, or a skull more or less entire, from the Chalk of Kent, or the Upper Green-sand of Cambridge, has been welcomed for the fuller information so yielded; and such fossils, with a few detached vertebræ and wing-bones, have expanded our conceptions of the bulk attained by some of the Flying-dragons at the decline of the Mesozoic period.

When the waters over which they flitted had a clayey or muddy bottom it afforded a quieter resting-place to the dead body of the Pterosaurian therein entombed. So the first discovered specimen of one of these in the upraised petrified ocean-bed now forming the Liassic cliffs of western Dorsetshire afforded BUCKLAND[1] subjects, in the compass of a slab about a foot square, for a description and figures of the leg and wing-bones, with part of the

[1] "On the Discovery of a New Species of Pterodactyle in the Lias at Lyme Regis." By the Rev. W. Buckland, D.D., F.R.S., F.G.S. (Read Feb. 6, 1829.) 'Transactions of the Geological Society of London,' second series, 4to, vol. iii, 1835, p. 217, pl. xxvii.

vertebral column, of the species which he called *Pterodactylus macronyx*—the first evidence of the genus from deposits so low, or ancient, in the Oolitic series.

In 1858 I obtained the skull, with a few other parts of the skeleton of the same or a closely allied species, from the Lower Lias at Lyme Regis, and communicated a brief notice of it to the British Association, which that year met at Leeds.[1]

This specimen confirmed the accuracy of Buckland's conjecture, which I had doubted, viz., that the portion of lower jaw with the series of small lancet-shaped, close-set teeth,[2] in a second slab of Lias, belonged to the same Pterodactyle as the limb-bones he described; but it also showed that these teeth, so like those of some Fishes, were limited to the lower jaw, and were associated, in the same mouth, with long, slender, trenchant and sharp-pointed laniaries, projecting with wide intervals, and set in advance; which kind of teeth had, hitherto, alone been found in the different species of flying Reptiles.

The chief result of the study of the second discovery of a Pterosaurian in Lias, viz., its evidence of a new generic form (*Dimorphodon*) in the order of volant *Reptilia*, in addition to *Ramphorhynchus*, von Meyer, and *Pterodactylus* proper, was noted in the communication above cited.

The third specimen about to be described confirms that taxonomic deduction, showing a combination of the caudal character, mainly differentiating *Ramphorhynchus* from *Pterodactylus*, with the dental character above defined.

I propose first to describe and figure the two specimens yielding the cranial and dental characters of *Dimorphodon*, and then to attempt a restoration of the Liassic species, *D. macronyx*.

The first specimen with the skull is figured in Pl. XVII. It is on a slab of Lias, measuring 11 inches by 7 inches. The right side of the head is exposed:[3] it has been subject to pressure and some degree of dislocation. Certain bones of both wings, and a few other parts of the skeleton are preserved, pell-mell, in this slab, pressed amongst and upon the bones of the head, especially at the back part of the skull.

The right premaxillary (22), maxillary (21), and nasal (15), are almost in their natural positions, give the profile contour of that part of the skull, show most of the teeth of the right side upper jaw, and reveal the singular expansion of the nasal (*n*) and antorbital (*a*) vacuities. The alveolar part of the left maxillary (8′), with its ascending postnarial branch has been pushed obliquely downward, with fracture, but without much displacement, of the beginning of the alveolar ray, the inner surface of which is exposed.

The mandible (32) has been dislocated and pushed below the place of its articulation with the tympanic (28): the left ramus has also been subject to the same force which has

[1] "On a New Genus (*Dimorphodon*) of *Pterosauria*, with Remarks on the Geological Distribution of Flying Reptiles;" in 'Reports (Sections) of the British Association,' 1858, p. 97.

[2] Buckland, loc. cit., pl. xxvii, fig. 3.

[3] The specimen has been drawn, in Pl. XVII, without reversing.

dislocated that side of the upper jaw; the hind part of this ramus is obliquely depressed, so as to expose the inner surface (32).

The anterior entire or undivided part of the premaxillary (22) is about 2 inches in length, and $1\frac{1}{4}$ inch in vertical height at its back part: it contains four pairs of teeth, which are the largest and longest of the series. The foremost tooth (1) is terminal, with a crown 5 lines in length, rather over 1 line in breadth (fore-and-aft) at its base; it is subcompressed, subrecurved, and sharp-pointed. An interval of 4 lines divides it from the second tooth (2), with a crown $5\frac{1}{2}$ lines long. After an interval of 7 lines projects the crown (3) of the third tooth, 7 lines in length and 2 lines in basal breadth, sharp-pointed like the first, but less bent. The socket and base (?) of the fourth tooth appear at an interval of 6 lines, and below is the entire and displaced homotypal tooth (4′) of the left side, showing the cavity on the inner side of its root which would have received the successional laniary. This tooth measures 1 inch 2 lines in total length, of which the exposed enamelled crown forms two-thirds. In advance of the foremost tooth (1) is seen part of its homotype (1′) of the left side, also displaced from the socket, and showing the depression and vacuity on the inside of the base, in relation to the succeeding tooth. Beyond the fourth alveolus the maxillary (21) appears, underlapping the part of the premaxillary (22″) which defines the lower and anterior part of the narial vacuity: the maxillary is continued straight backward, with feeble indications of two crushed alveoli (5, 6) for 1 inch 9 lines, when the seventh laniary (7) projects almost straight downward: the crown of this tooth is 5 lines long; the root, covered with rougher cement, slightly contracts to its implanted end, which has slipped a short way out of its socket. An interval of 4 lines divides this from the next laniary (8), which shows a crown of but 3 lines in length; this projects opposite the fore part of the lateral post-narial branch (21^{x}) of the maxillary. The base of the left homotypal tooth (8′) projects from the same part of the dislocated left alveolar branch of the maxillary; and above this, on the inner side of that bone, is exposed the coronal germ of a successor. In the right maxillary two other straight laniaries (9, 10) of rather decreasing length, project with similar or rather lessening intervals: then follows, after an interval of 3 lines, a pointed compressed crown $1\frac{1}{2}$ line in length (11); and, at shorter intervals, two smaller pointed compressed teeth (12 and 13).

These thirteen cuspidate teeth of the upper jaw are included in an extent of the alveolar border measuring 5 inches 2 lines. That border is continued backward, straight and edentulous, for 9 lines beyond the last tooth, when it is crossed by the large and long first phalanx (*if* 1) of the wing-finger. This edentulous part of the maxillary forms the lower straight border or base of the large triangular antorbital vacuity (*a*), at the back part of which it is overlapped by the fore part of the slender malar (26). Above this vacuity are parts of the nasal (15) and prefrontal (14), both somewhat displaced in this crushed part of the skull. The arched part of the frontal forming the upper part of the rim of the orbit (*o*) is recognisable at (11) Pl. XVII. Above its hind part are indications of the post-frontal (12) and mastoid (8), with the process of the latter descending external to

its articulation with the tympanic (28). The metacarpus and dislocated unguiculate digits of the wing-limb are confusedly interblended with the crushed and dislocated back part of this skull; three phalanges (*IV* 1, *IV* 2, *IV* 3) of the wing-finger are determinable.

The two anterior teeth (1′, 2′) of the mandible show longitudinal angular depressions at their base, indicating exposure of their inner side, and that they belong to the left ramus. The corresponding part of the right ramus may have been broken away: the third laniary (3′) clearly belongs to this ramus, which is fractured beneath its socket. The point of this tooth is broken off: what remains of the body is curved, and is implanted more obliquely backward than the two preceding teeth. This at first led me to suspect it might be the foremost tooth of the mandible, and that the left ramus had been pushed in advance as well as downward: but my doubts on this point have been set at rest by the specimen (Pl. XVIII) next to be described, and I view the tooth in question as the third of the mandibular series: it is divided from the second by an interval of 6 lines, and the second stands at a rather shorter interval behind the first. Five lines behind the third tooth is the base of a fourth laniary (4′), and four lines further back is an indication of a fifth (5′). This is followed by the characteristic series of between thirty and forty very small, subcompressed cuspidate teeth, each less than a line in length, corresponding in extent with the maxillary part of the upper jaw. The entire series of mandibular teeth occupies an extent of alveolar border measuring 5 inches 1 line.

The depth of the right ramus gradually increases from 5 lines below the last laniary to 10 lines below the last denticle. The inner side of the dislocated ramus (32′) shows a strong longitudinal ridge projecting inwards about 3 lines above the lower border. The outer surface of the ramus seems to have been strengthened near its lower border by a similar but lower ridge.

The distal ends of the antibrachial bones (54, 55) overlap the hind part of the mandible: that which shows the larger articular surface, opposite the three slender metacarpals, should be the radius. The base of the supplementary styloid bone appears near the distal end of the ulna, but is better shown in Buckland's original specimen.[1] Indications of two carpals intervene between these and the metacarpus. This overlies and conceals the articular pedicle of the mandible and contiguous parts (squamosal, malar, &c.) of the skull. The metacarpus includes the three slender supports of digits *I*, *II*, and *III*, and the strong and thick metacarpal of the wing-finger (*IV*). This bone, being almost concealed by the first phalanx in Buckland's specimen, was overlooked, and that phalanx was described as the metacarpal of the wing-finger, which, accordingly, in the restoration, fig. 2, Pl. 27, of 'Buckland's Memoir,' is made three times the length of the other and more slender metacarpals (3′). I have, therefore, had that part of the original specimen, now in the British Museum, redrawn (Pl. XIX, fig. 1), the true metacarpal being shown at *m* 4. It corresponds with the same bone in previously described *Pterosauria* by surpassing in thickness, not in length, the other constituents of the metacarpus. In the specimen,

[1] As in the part re-drawn in fig. 1, Pl. XIX.

Pl. XVII, the metacarpal of one wing-finger is clearly shown at $_{IV}m$. That of the other, lying upon the cranium, is more obscure. The thin compact wall of this pneumatic bone has been crushed in upon the wide air-cavity, as with most of the other long bones, so that it looks like two metacarpals. The proximal articular surface of $_{IV}m$ is partly concave and partly convex: the distal articulation is trochlear, moderately concave from side to side at the middle, convex from behind forward, with a depression behind, above the articulation, for securing the olecranoid process of the proximal phalanx. This phalanx ($_{IV,}$ 1), in one wing, is bent back upon the fore-arm, crosses the dislocated mandible, and has been pressed upon it, long and hard enough to leave a channel in the right ramus, where part of the phalanx has been removed: its length is 4 inches 6 lines.

The second, more slender and longer phalanx ($_{IV,}$ 2), is bent at nearly a right angle with the first, and lies below and parallel with the mandible: it is nearly 5 inches in length. The third phalanx ($_{IV,}$ 3) is bent upward in front of both lower and upper jaws: $4\frac{1}{2}$ inches of its length is preserved in the slab: from the analogy of the better preserved specimens (Pl. XVIII, $_{IV,}$ 3), about 1 inch 3 lines are wanting from the distal end.

Of the three unguiculate digits the characteristic large claws are preserved: one ($_{II}$) lies above the frontal (11) with the penultimate phalanx; the other two are between the upper and lower jaws, with some of the slender phalanges: all these parts of the ramus having been dislocated and scattered.

Parts of the distal ends of the radius and ulna (54′, 55′), the metacarpal of the wing-finger ($_{IV}m'$), and the proximal end of its first phalanx ($_{IV}1'$), of the opposite fore-limb, occupy a lower corner of the slab: carpal bones, one of the accessory styloid ossicles of the forearm, some of the slender metacarpals of the claw-fingers can be made out above these: and there are more obscure indications of vertebræ at that end of the slab, curving toward the cranium.

All the osseous and dental textures are black, as if charred by slow combustion of the animal matter.

Dimorphodon macronyx. Pl. XVIII.

In August, 1868, I was favoured by the Earl of Enniskillen, then at Lyme Regis, Dorsetshire, with a list of parts of a Pterodactyle, in a slab of Lias about 20 inches by 11 inches, and of other parts in detached portions of Lias, including the entire tail with its bone-tendons, which his Lordship had observed at Messrs. James and Henry Marder's, the judicious and persevering collectors of the fossils of that rich locality.

The result of this valuable and timely information was the securing for the British Museum the entire series of these Pterosaurian fossils.

They proved to be parts of the *Dimorphodon macronyx*, confirmed many of the observations made on previously acquired specimens, corrected others, and added almost all that was required for the restoration of the skeleton of this remarkable genus and species, which I have accordingly attempted in Pl. XX.

The slab of Lias with the second specimen, including the skull of *Dimorphodon macronyx*, is of larger size, shows more of the skeleton and in a more separated and definable state than in Pl. XVII. Nine dorsal vertebræ, third to eleventh inclusive, in natural juxtaposition, with the twelfth slightly dislocated, are preserved at the upper part of the slab (Pl. XVIII, D). The summits of the neural spines (*ns*) of most of these, and the disposition of many of the preserved ribs, show that they lie mainly with the dorsal aspect downward (as the specimen is figured). This explains and accords with the position of the parts of the pelvis, which lie a little way behind the dorsal vertebræ. The comparatively slender ilium ($_{62, 62}$) is downward ; the broad ischium ($_{63}$), and the pair of spatulate pubic bones ($_{64}$), are turned, like most of the ribs, upward, as I conclude the abdominal or ventral surface of the trunk was directed as the fossil lies in the figured slab. The bones of the hind-limb, in connection with the acetabulum, are turned outward, with their inner surface exposed. The projections of the trochlear terminations of the metatarsals ($i, iv, _{69}$), show that the sole of the foot is turned to view. Accordingly, we have here the bones of the left hind limb. On the hypothesis that the femur and tibia are seen from the outside, which at first suggests itself, they would belong to the right limb, viewed in profile. But then, the broad thin plate of bone contributing to the acetabulum, would represent the ilium, and the indications of the pelvis below the acetabulum and head of the femur would represent ischium and pubis. This interpretation, however, gives to *Dimorphodon* proportions of pelvic bones very different from those determined by Wagner in *Pterodactylus Kochii*,[1] and by Quenstedt[2] in *Pterodactylus suevicus;* and, besides, it leaves undetermined the pair of bones (64, Pl.XVIII) which closely resemble in form and proportion the 'pubic bones' (u, u) in Quenstedt's instructive plate.[3] In this plate the ilia (s, s) are represented as long slender bones, contributing the upper but smaller proportion of the acetabulum, and extending horizontally beyond it both forward and backward. The pelvis, in the position in which I conclude it to lie in the slab figured in Pl. XVIII, might well afford such indications of the pre- and post-acetabular productions of the ilium as are there shown at $_{62, 62}$. In *Pterodactylus suevicus* the ischium contributes the lower and major half of the acetabulum (*tr*, loc. cit.), and expands into a broad thin plate (*s*, ib.), having the proportions to that of the spatulate pubis, which the bone $_{63}$ bears to $_{64}$, in Pl. XVIII. The portion of the pelvis in the original specimen being preserved in natural connection with

[1] "Ueber *Ornithocephalus Kochii*," in 'Abhandl. d. math.-phys. Klasse der Bayerischen Akad.,' ii, 4to, München, 1837.

[2] 'Ueber *Pterodactylus suevicus*,' &c., 4to, Tübingen, 1855.

[3] In the Memoir above cited.

the sacrum and contiguous vertebræ is figured in Pl. XIX, fig. 2; and the constituent bones are rightly recognised by Buckland (op. cit., p. 222).

It is interesting to note, that the pelvis of *Pterosauria*, so determined, resembles more closely that of the existing representatives of the section of *Reptilia* with the 4-chambered heart and double-jointed ribs, viz., *Crocodilia*, than it does the pelvis in *Chelonia* and *Lacertia*. The ischium in *Crocodilia*, *e. g.*, surpasses the pubis in size, and excludes that hæmapophysis from the acetabulum.[1] The ischium seems to contribute the larger share of the acetabulum in *Dimorphodon*, Pl. XVIII, *a*. In Birds, as in Lizards, the pubis forms part of the acetabular cavity.[2]

In the specimen, Pl. XVIII, a portion, *cd*, of a long tail, of which the vertebræ were surrounded by numerous slender bone-tendons, extends backward and downward beyond the pelvis: a better preserved portion with three caudal vertebræ (*c d'*) is preserved in a detached part of the matrix found in the vicinity of the larger slab. But to this part of the vertebral column I shall return in describing the more perfect specimen of the tail of *Dimorphodon*, from another individual (Pl. XIX, fig. 4).

Behind the skull are four cervical vertebræ (Pl. XVIII, c), and part of a fifth in natural juxtaposition, or perhaps a little separated at the articular surfaces. The under surface of the centrums and articular processes of the neural arches are exposed. The sides of the centrums show a slight concavity, but their crushed state obscures the natural contour of the under surface. The hind part of the under surface, in the last two of these vertebræ, shows a pair of low obtuse processes, with an indication of a convex terminal articular surface. The centrum expands in breadth as it advances, and sends out a short thick process (parapophysis) from each side of the fore part; to which, in the last three vertebræ, are indications of attachment, or parts, of a backwardly produced styliform rib. At the midline of the fore part of the last two of these vertebræ a fracture indicates a ridge or process there to have been broken off. The pre-zygapophyses are thick, and project far in advance of the concave anterior articular surface of the centrum: the convex posterior articular surface of the centrum projects as far beyond the post-zygapophyses. Their joints are more vertical than horizontal: the posterior surfaces looking slightly outward and downward.

The superior breadth of the neural arch, as compared with that of the centrum, brings its articular processes into view, along each side of the vertebral bodies, in the degree shown in Pl. XVIII, c. The character of the articulations indicate less extent and freedom of movement of the cervical vertebræ than in Birds, and more restriction in the lateral than in the vertical directions. The interlocking joints resulting from the different lengths of the fore and hind articular processes add strength to the part of the spine supporting the head.

The cervical vertebræ of *Dimorphodon*, so far as their structure is exemplified in the

[1] 'Anatomy of Vertebrates,' vol. v, p. 188, fig. 119.

[2] Ib., p. 190.

present specimen, conform to the pterosaurian characteristics of these vertebræ, as shown in those of *Pterodactylus Sedgwickii*, described and figured in the 'Monograph on the Fossil Reptilia of the Cretaceous Formations,' Supplement No. 1 (1859), pp. 7—10, Pl. II, figs. 7—18; and in those of *Pterodactylus simus*, ib. Supplement No. III (1861), p. 7, Pl. II, figs. 1—5.

The skull preserved in the present specimen agrees in size with that in the slab previously received (Pl. XVII), repeats the characteristics of the genus *Dimorphodon*, and shows no differences of greater degree or value than may be set down to individual modifications. The part defective and partly obscured by intrusive bones from other parts of the skeleton is unfortunately that which leaves the precise determination of structure unsatisfactory in the previously described specimen. A trace only of tympanic remains at 28, and of the descending styloid process of the mastoid at 8: the thick metacarpal of the wing-finger (iv, *m*), intrudes into the orbit, and overlaps the upper end of the malar (26). More of the part of the frontal forming the superorbital arch (11) is shown than in Pl. XVII. Part of the concave surface of the orbital cavity beneath the superciliary ridge is here seen. The lacrymal (23) or descending branch of the prefrontal (14) meets the ascending process from the combined malar and maxillary, dividing the orbital from the antorbital cavity. The true size and shape of the latter vacuity (*o*) is here well displayed. The maxillary styloid process (21^{x}) rises, at the same angle backward as in Pl. XVII, to join the nasal (15). The medial branch or ray of the premaxillary (22′), the end of which is depressed below the prefrontal in Pl. XVII, preserves its position in the present specimen, and yields the true arched contour of the profile of this remarkable skull.

The entire vertical extent of the vast narial vacuity, *n*, is here given, the longitudinal one, $3\frac{1}{2}$ inches, precisely agreeing with that in the first-described skull. The anterior part of the premaxillary (22) shows, also, the same proportions and shape, viewed sideways, as in the first specimen. The conformity is instructively continued in the characters of the dental system. The apex of the crown of the laniary (Pl. XVIII, 1) from the fore end of the premaxillary shows the same curvature and proportions as in Pl. XVII; the same interval divides it from the second laniary (2); the longer interval, again, occurs between the second and the third laniary, with a longer and less curved crown. After an interval of seven lines comes the fourth tooth (4), corresponding in size and shape with the one which is displaced in Pl. XVII, 4′. After an interval of nine lines the apex of the crown of, seemingly, the successor of the fifth laniary (5) appears. It may be, normally, smaller than the rest; the socket of this tooth is feebly indicated in the subject of Pl. XVII. The sixth laniary (6) shows the same size and relative position as in that subject, and the same may be said of the five succeeding teeth, save that the last is rather larger than in Pl. XVII, which also shows an additional small hind cuspidate tooth. The suture between the premaxillary (22″) and the maxillary (21) is more plainly discernible in the present specimen.

The extent of alveolar surface of the left upper jaw occupied by the above-described dental series is 5 inches 3 lines.

In the left ramus of the mandible two of the large anterior laniaries are in place; one, answering to the second in Pl. XVII, 2′, projects across the diastema betwcen the second and third tooth above; in size, shape, and curvature, it resembles the second upper laniary, close to which it terminates. The next mandibular tooth is larger, less curved, and crosses the middle of the interval between the third and fourth upper laniaries. The tooth (1′) displaced beneath the mutilated fore part of the mandible, I take to be the foremost of the mandibular series and suppose that its point would naturally project across the interval between the first and second of the upper teeth. The fourth laniary appears to be more displaced: its base or root, with a lateral depression, is shown behind the fifth tooth of the minute serial teeth, and the crown passes obliquely backward on the inner side of that of the sixth upper laniary, by which it is concealed. Of the serial teeth, with pointed crowns from half a line to a line in length, about thirty may be reckoned occupying an alveolar extent of 2 inches, 9 lines.

At the hind part of the left mandibular ramus, here exposed, three longitudinal ridges define two vacuities, of which the inferior may be natural. The upper one seems more plainly due to loss of the thin outer plate of bone extended between the upper two ridges. The proportions of the ramus closely accord with those of the first-described specimen. The fore part of the mandible is too much mutilated for useful comparison.

The dentition of *Dimorphodon*, as displayed by the second specimen of skull, consists, in the upper jaw, of laniaries with wide intervals, eleven in number on each side; in the lower jaw, of four, if not five, laniaries implanted at the fore part of each ramus of the mandible at intervals corresponding with three of the four anterior laniaries above; then follows the long series of close-set and minute pointed teeth. The difference of dentition as compared with the first specimen (Pl. XVII) is, in the upper jaw, in the additional small laniary or cuspidate tooth at the back part of the series in that specimen. In the lower jaw there does not seem to be any noteworthy difference in the number, kinds, and position of the teeth. The longest laniaries are included between the second and fifth in both jaws: the upper laniaries after the fourth become small and straight.

At the first view of the framework of the huge head of our Liassic dragon one is struck with the economy of bony material and the purposive skill with which it has been applied or disposed, so as to give strength where resisting power was most required.

The lodgment of the poorly developed brain enlists a miserably small proportion of the skull: the cranium proper, or brain-case, is relegated to an out-of-the-way corner, so to speak, and there it is almost concealed by the projections for joints or muscular attachments. The orbits accord with the large eyes given to this volant and swift-moving Reptile.

One can conceive no necessary interdependent relation between the wide external bony nostril (*n*) and the organ of smell, nor be led to conjecture that the tegumentary inlets to the nasal chamber were larger than is usual in Reptiles.

The main purpose of the head is for prehension of prey. The jaws are produced far

forward to form a wide-gaping mouth, and are formidably armed. We may conceive, therefore, that the dragon may have occasionally seized an animal of such size as to require considerable force of jaw for overcoming its struggles. The means of resistance were afforded to the upper or fixed maxilla, not by a continuous wall of bone, but by curved columns or abutments. The chief of these is the upper medial arch of bone which overspans the skull lengthwise, from the short roof of the cranium to the fore part of the premaxillary (22); the frontals (11) and nasals (15) combining with the mid-fork or branch of the premaxillary (22′,) to constitute this arched key-ridge of the roof of the head.

From it two piers or buttresses out-span on each side, to give strength and resistance to the upper jaw, and especially its alveolar tracts. One, proceeding from the nasal, meets the uprising process of the maxillary (21); this abutment, curving from above outward and obliquely forward, expands and backs the part of the jaw where the second group of large laniaries project. The second buttress is continued from the prefrontal (14), and arches more directly outward to meet the uprising process of the malo-maxillary. A third arch, due to the post-frontal (12) and malar (26), expands to abut upon the hind end of the maxillary arch, and gives support to the part of the skull which the temporal muscles tended to pull downward when they were giving to the mandible the power of a strong bite or grip. Finally, comes the strongest of the four piers, due to the mastoid (8) and tympanic (28), for giving articular attachments to the rami of the lower jaw.

Thus, four vacuities appear in the side-walls of the skull: the first (*n*) is the largest, between the small consolidated or continuous fore part of the skull (22), and the naso-maxillary pillar (21^{x}, 15). This vacuity answers to the external bony nostril of the same side, in the Lizard's skull (Pl. XX, fig. 3, *n*), where the nostrils are divided and more or less lateral. The second vacuity (*a*) is somewhat less, of a triangular form, with the base downward: it answers to the antorbital vacuity in *Lyriocephalus* (ib., *a*) and a few other Lizards, and to that in *Teleosaurus*, where, however, it is very small. The third vacuity (*o*) still decreasing, is oval, with the narrow end or apex downward: it answers to the orbit, but is of large size compared with most Saurians; it is, however, exceeded in relative expanse by the orbit in *Lyriocephalus* (ib., *o*).

The fourth vacuity is the narrowest: it answers to the so-called 'temporal fossa' and was occupied by the muscles of the same name. Extension of surface, for their origin, and additional strengthening of this back part of the skull are gained by laying horizontally across the temporal fossa the bony beams called 'upper and lower zygomata,' arching from the postfronto-malar to the masto-tympanic vertical columns. The heavy phosphate of lime, thus singularly economised by the disposition of the bones on mechanical principles plainly to that end, is made to go still further by the arrangement of the osseous tissue. Every bone is pneumatic, the abundant, open, cancellous structure being included in a very thin layer of compact osteine.

The bones of the limbs are dislocated and dispersed in the way and degree common to the specimens of this animal hitherto discovered (Buckland, loc. cit., pl. xxvii; and pls. XVII and XVIII of the present Monograph). The scapula (Pl. XVII, 51) and coracoid (ib., 52) in the same anchylosed condition as in the first-described specimen, are at the end of the slab opposite to that with the head. The corresponding humerus (53), preserved in a separate portion of the block of Lias, shows the entire contour of the pectoral process (*b*). The right humerus (53′) lies below the dorsal vertebræ (D); the upper part of the pectoral proeess (*b*) is wanting, but the obtuse thickening of the end of that remarkable production is well shown. The ridge (*c*) called 'ulnar,'[1] descending from the 'lesser tuberosity,' appears in this view of the 'palmar' surface of the bone.[2] The sigmoid flexure of the shaft is much better marked than in the humerus of *Pterodactylus suevicus*.[3] The stronger walls of the humerus have resisted the pressure better than those of most of the other long bones.

Of the antibrachial bones parts of the shafts, erushed, are seen at 54, 55, apparently of the right wing. With the distal ends of these, the right carpus (56) and metacarpus (57) appear to have retained their natural connections. The slender metacarpals of the first (I), second (II), and third (III) digits appear emerging from beneath the left hind foot which overlies their proximal ends. The phalanges of the first digit (I), two in number, preserve their natural articulations. As are also those of the seeond digit, three in number. The metacarpal of this digit is longer by $2\frac{1}{2}$ lines than that of the first. The additional phalanx would seem to be the proximal one, by its shortness: the second phalanx more nearly agrees in length with that supporting the claw-phalanx in the first digit; but it is thicker and a little longer. The four phalanges of the third digit (III) are dislocated; but the penultimate, which is the longest, retains its connection with the ungual phalanx. The proximal phalanx is longer than the second, which resembles in length, and seems homotypal with, the proximal phalanx of the second digit. It may be concluded, therefore, that the additional phalanx to II and III was developed at the attachment of the digit to the metacarpus. The largely and abruptly expanded metacarpal of the fourth digit is in great part covered by the correspondingly thickened and much elongated phalanx (*IV*, 1) therewith articulated. The olecranoid process of this phalanx is well shown, and the entire bone is preserved: its length is 4 inches 2 lines: it is bent directly and abruptly back upon its metacarpal. To the distal end is attached part of the second phalanx (*IV*, 2).

The proximal phalanx of the left wing-finger is preserved in a detached (*IV*, 1) part of the slab (Pl. XVIII) containing the major part of the skeleton. The second phalanx (*IV*, 2′) of the left wing-finger lies in that slab, is entire, and yields a length of 4 inches 9 lines. The third

[1] 'Monograph on Fossil Reptilia of Cretaceous Formations,' Suppl. No. iii, 1860, p. 14, pl. iii, fig. 1, *c*.

[2] Op. cit., 190.

[3] Quenstedt, op. cit., *c l*, *c r*.

phalanx ($_{IV,3}$) is 5 inches 6 lines in length; near its distal end is part of the slender terminal phalanx of this digit ($_{IV,4}$). There is no trace of a fourth unguiculate digit, and I return to Cuvier's view of the structure and homologies of the hand of the Petrodactyle,[1] which I had abandoned in favour of the seemingly more perfect evidence supporting Professor Goldfuss' restoration of *Pterodactylus crassirostris*,[2] adopted by Buckland[3] and myself.[4]

The metacarpal of the left wing-finger ($_{IV,m'}$, Pl. XVIII) lies beneath the back part of the skull, and is over-lapped by the superorbital part of the frontal. Portions of two of the unguiculate digits of the same fore-paw ($_{I,II}$) are seen in the wide narial vacuity.

The definition and finish, so to speak, of the joints of the wing-finger are worthy of note, especially of that between the metacarpal bone and proximal phalanx. In Reptiles generally the articular extremities of the long bones are not very definitely sculptured, and do not manifest that reciprocal adaptation of their inequalities which are observed in the joints of Mammals and Birds. The difficulty of determining the coadapted extremities of detached bones of Reptiles is increased by the great thickness of the cartilage which covers them and renders their mutual contact more intimate, and which is always wanting in fossil bones. The Pterosaurian modification is, however, purely adaptive; and the relation to Warm-blooded Vertebrates in this respect is one of analogy. An argument in favour of avian affinity from the joint-structures could only be propounded by one not gifted with the judgment needed to deal with problems of this nature.

The left femur (65′) preserves its natural articulation with the acetabulum; the head is bent forward from the line of the shaft for an extent like that at which the condyles are produced backward; the shaft is straight, the great trochanter is feebly developed. There is no evidence of a modification of the distal condyle for the interlocking articulation with the fibula, which in Birds relates to their bipedal station and walk. The length of this femur is 3 inches 4 lines

The left tibia (66′), bent back at an acute angle upon the femur, measures 4 inches 10 lines in length. There is no trace of patella, nor has this sesamoid bone been found in any Pterosaur. The inner side of the bone being exposed, the styliform rudiment of the fibula is hidden from view. The trochlear termination of the distal end of the tibia is better marked than in *Crocodilus*, or even than in *Scelidosaurus* ('Monograph on Oolitic Reptilia,' Part II (1863), p. 16, Pl. X, 66), and consequently approaches more nearly to the characteristic form of the joint in Birds. The resemblance to the bicondyloid termination of the femur is instructively shown in the distal portion of the Pterosaurian tibia figured in Pl. XIX, figs. 8 and 9, and in the distal half of the right tibia of *Dimorphodon*

[1] 'Ossemens Fossiles,' 4to, v, pt. ii, p. 371.

[2] Beiträge zur Kentniss verschiedener Reptilien der Vorwelt, in 'Nova Acta Acad. Natur. Curios.,' Leopold Carol., &c., 4to, tom. xv. "Reptilien aus dem lithographischen Schiefer, *Pterodactylus crassirostris*, nobis, tabs. VII—X."

[3] 'Bridgewater Treatise,' 8vo, 1836, pl. 22.

[4] Owen's 'Palæontology,' 8vo, 1861, fig. 97.

in the slab, Pl. XVIII, at 66, which crosses the right antibrachium (54, 55). The deflected posterior ends of the condyles are here shown, and beneath them three tarsal bones (*o*, *l*, *b*), with the characteristic short and thick metatarsal of the fifth toe (*m*, *v*).[1]

The tarsal bone between the tibial trochlea and the three metatarsals (*i*, *ii*, *iii*), answers to the astragalus, marked *a*, in *Scelidosaurus* and *Crocodilus* (Monograph and Plate above cited); two tarsals, of which the one representing the second row is the smallest, intervene between the tibia and the fifth metatarsal; the larger of these ossicles answers to the calcaneum (*l* in *Scelidosaurus* and *Crocodilus*, Monograph, *ut suprâ*), the smaller and distal one to the cuboides (*b*, *ib.*).

The bony frame-work of the left foot (69′) is instructively preserved; the first four metatarsals are, as usual, long and slender, and resemble those in previously described *Pterosauria;* their under or plantar surface is exposed. The metatarsal of the first or innermost toe (*i*) is the shortest, that of the fourth toe (*iv*) is next in length; the third (*iii*) is the longest, but there is little difference in this respect; their distal condyles project toward the sole, and are made trochlear by a mid-groove.

The innermost digit shows the proximal and ungual phalanges in natural connection with each other and with the metatarsal: the ungual phalanx (*i*) is scarcely half the size of that of the corresponding digit (*i*) of the fore-foot. The ungual phalanges of the three other toes (*ii*, *iii*, *iv*) are preserved, showing the usual uniformity of size in the hind-foot of *Pterosauria:* the number and disposition of the contiguous but scattered phalanges best accord with the phalangeal formula (3, 4, 5) presented by the second, third, and fourth toes respectively, in better preserved feet of other *Pterosauria* (Pl. XIX, fig. 5). There is, however, here unequivocal evidence of a fifth toe, and that not merely rudimental but recognisably functional though without a claw. The tarsal bones (*b*, *b*) support a metatarsal (*m*, *v*) directed parallel with the metatarsals (*i*—*iv*), but much shorter and also thicker: it is 6 lines in length, and expanded at both ends, the proximal one being $2\frac{1}{2}$ lines in breadth, the distal one 2 lines, and the middle of the shaft $1\frac{1}{2}$ line. The under or plantar side of the bone is exposed, as in the others, and shows a shallow oblique channel passing from the proximal end obliquely to the inner side of the shaft, dividing two elevations at that aspect of the proximal end. The distal end is a moderately convex condyle, the outer and plantar prominence of which is broken off. I regard this bone as the fifth metatarsal. It supports a digit of two phalanges: the first (1, *v*) is slightly dislocated, so as to show the concavity of its proximal joint close to the condyle to which it was articulated: it is 1 inch 3 lines in length, and is thicker as well as much longer than the corresponding phalanx of the other toes. The second phalanx (2, *v*) is 1 inch in length: it is bent back upon the first, and gradually tapers to a point. Both phalanges,

[1] This throws expository light on the idea, revived by Gegenbaur ('Vergleichend-anatomische Bemerkungen über das Fussskelet der Vögel,' in Reichert's 'Archiv für Anatomie, Physiologie, und wissensch. Medicin,' 1863, p. 445), viz., that the distal trochlear epiphysis of the Bird's tibia represents its proximal tarsal series, or astragalus.

in the specimen described, pass obliquely across and beneath the four long metatarsals supporting the unguiculate claws.[1]

From the position of this exunguiculate long and slender toe, as well as from its difference of structure, we may infer its application to a different office from that of the other toes. These obviously subserve the purposes of terrestrial locomotion, and perhaps of suspension: the fifth toe I infer to have helped to support, like the similarly shaped production of the calcancum in certain Bats, the interfemoral expansion of alar integument, in the way indicated in the restoration (fig. 2, Pl. XX) of *Dimorphodon macronyx*. In the habitual mode of locomotion by vigorous act of flight this toe would be in action while the other four were at rest; hence the necessity for greater thickness and strength of its bones, and the size of one of the tendons, as indicated by the groove in the metatarsal. Interesting, also, is it to note the analogy of this 'wing-toe' with the 'wing-finger,' though they be not homotypes, as shown in the shortness as well as thickness of the metapodial bone and the length of the pointed, clawless, terminal phalanx.

The fourth slab of Lias adding to our means of reconstruction of *Dimorphodon*, was observed by the Earl of Enniskillen in the collection of Henry Marder, Esq., M.R.C.S., of Lyme Regis. It had been quarried from the same cliff as the preceding specimen (Pl. XVIII), and displayed the vertebræ and bone-tendons of a long and stiff tail (Pl. XIX, fig. 4).

Indications of such a tail, in which the vertebræ were associated with ossified tendons, were apparent, and have been noted in the description in the second specimen with the skull (Pl. XVIII, cd); whereby one was able to show that the vertebræ in the originally described specimen supposed to be cervical (Buckland, loc. cit., pl. xxvii, *a*, *a'*) were truly caudal, with similarly associated bone-tendons, as, indeed, *Von Meyer* had recognised after the discovery of the caudal structure of his *Ramphorhynchus*.[2] The specimen now to be described of the entire tail, as represented by its petrifiable parts (Pl. XIX, fig. 4)[3] I conclude, from the identity of character of some of its vertebræ with the three shown in Pl. XVIII, *c d'*, and from the discovery of this specimen in the same formation and locality, to belong to *Dimorphodon macronyx*.

The series of caudal vertebræ, to judge from the size of the anterior ones, comes from an individual as large as that represented by the fossils in Pls. XVII and XVIII, and, no doubt, from an adult or full grown one. This series is 1 foot 9 inches in length, following the curve,

[1] "Cuvier, Wagler, und Goldfuss lassen den Fuss aus fünf ausgebildeten Zehen bestehen; in allen Pterodactyln habe ich aber nie mehr als vier solchen Zehen und höchstens noch einen Stummel vorgefunden." Von Meyer, op. cit., p. 20. But see 'Ossemens fossiles,' 4to, tom. v, pt. ii, p. 374—"Le cinquième réduit à un léger vestige," &c.

[2] "Beiträge zur näheren Kenntniss fossiler Reptilien," in Leonhard und Bronn's 'Neues Jahrbuch für Mineralogie,' &c., 8vo, 1857, p. 536.

[3] It has been drawn with the neural aspect downward.

which is single and slight; and it includes upwards of thirty vertebræ. These vertebræ, 3 lines in length of centrum in the first five, progressively increase to a length of 1 inch at the twelfth, begin to shorten gradually after the fifteenth, the twenty-first being 11 lines, the twenty-fourth 9 lines, the twenty-eighth 6 lines, and the thirtieth 5 lines in length. In breadth or thickness the vertebræ decrease from the first to the tenth; and then again gradually from the fifteenth to the last, which is filiform.

The first caudal, or the first of the series here preserved, has the anterior articular surface of the centrum subconcave. The inferior surface describes a slight concavity lengthwise; the upper part of the anterior half projects as a parapophysis, the end of which has been broken off, showing the open cancellous structure. A ridge from its upper part was continued to the fore part of the anchylosed neural arch. This arch developed zygapophyses, of which the anterior extend beyond the centrum; but they are better shown in succeeding vertebræ.

In the second caudal the base of the parapophysis has receded and now projects from the upper part of the side of the centrum, occupying more than its middle third. Part of a quadrate spinous process is here preserved, projecting above the centrum as far as the vertical diameter of that element.

In the third caudal the base of the parapophysis, reduced in vertical thickness, occupies the same positions and longitudinal extent. The postzygapophysis, after a deep hind notch of the neurapophysis, curves over the prezygapophysis of the succeeding vertebra, which enters that notch.

In the fourth caudal the base of the parapophysis has lost in longitudinal as well as vertical extent, and is more posterior in position. The subconvexity of the hind articulation of the centrum is here well shown. The confluent neural arch is low, attached to rather more than the fore half of the centrum. The postzygapophysis does not extend back beyond the centrum; the prezygapophysis is continued beyond the front or concave surface of the centrum into the neural notch of the preceding vertebra.

In the fifth caudal the parapophysis is smaller and more posterior. The neurapophysis rises from the anterior half of the side of the centrum and continues to show the zygapophysis, though reduced in size. Between the fifth and sixth caudals a small, slender hæmapophysis (*h*) has been articulated to the under part of the intervertebral space.

The reduced parapophysis is continued from the sixth caudal; this vertebra shows a much reduced indication of neurapophysis. The base of a hæmapophysis crosses the lower part of the space or joint between it and the seventh caudal, then expands both forward and backward, and more so in the latter direction; the inferior border of this expansion is straight.

In the seventh caudal the prezygapophysis is still indicated, though much reduced in size. The hæmapophysis, similar in shape to the preceding one, is longer; and three bone-tendons rise from the side of the hind projection of this hæmal arch.

In the eighth caudal the base of a reduced parapophysis projects from the side of the centrum behind its middle; a low prezygapophysis projects from the neural arch: but beyond this vertebra all trace of that arch disappears, or is indicated by feeble prominences in the fasciculus of bone-tendons which seem to be attached to neural processes of the non-elongated centrums. Six or seven filamentary bone-tendons, one thicker than the rest, extend lengthwise above the centrum. Some of these may be traced over two centrums, then end in a point, their place being taken by another bone-tendon beginning by a similar pointed end. The parapophysis disappears in the tenth vertebra.

The caudal vertebræ in the first discovered specimen of *Dimorphodon*[1] answer to the eighth—eleventh in the present series. The elongate centrums of the tenth and succeeding caudals, usually more or less uncovered by the bone-tendons, show a low lateral ridge, and a slight expansion at the ends. The hæmapophyses are traceable, much reduced in size, to the fifteenth—sixteenth vertebræ. The bone-tendons are in two fasciculi, one neural, the other hæmal, in position. From five to eight may be counted in the side view given of each of these fasciculi. The seeming increase of thickness of some, usually the more peripheral of the filaments, may be due to this flattened form, and to more or less of the side coming into view, instead of the edge. Five or six may be counted in each fascicule, even beyond the twentieth caudal; the number varying at parts through the formation of the bundle by successive tendons, as above mentioned. They are reduced to two or three at the thirtieth vertebra. The terminal joints of the elongate centrums appear to be flattened and closely adapted, allowing of very little motion. It is evident that, as in *Ramphorhynchus*, the tail was stiff as well as long, and doubtless served as a sustaining ray of the parachute of membrane continued backwards from the wings and hind limbs.

The vertical diameter of the second caudal showing its neural spine is five lines. The diameter of the ninth vertebra, including the neural and hæmal fasciculi of bone-tendons, is the same; and beyond this the vertebræ and their surroundings gradually diminish to the pointed end of the tail.

§ Restoration of Dimorphodon. Plate XX.

The several parts of the skeleton of *Dimorphodon* preserved in the slabs of Lias described and referred to in the foregoing pages have ultimately yielded the desired result of their scrutiny and comparison, viz., a restoration of the extinct animal, such as I have endeavoured to exemplify in Plate XX; and I propose to apply that plate in illustration of a summary of the osteology and dentition of *Dimorphodon*, comparing therewith the

[1] Buckland, loc. cit., pl. 29, *a*, *a*. I have had these vertebræ carefully redrawn, from the specimen, in Pl. XIX, fig. 3.

previously known *Pterosauria*, and adding such deductions as to the status and affinities of the order as seem legitimately to flow from the facts.

The first distinguishing feature of *Dimorphodon*, or of the present liassic type of the genus, is the disproportionate magnitude of the head—the more strangely disproportionate, as it seems, in an animal of flight.

The head is large in proportion to the trunk, not only in respect of length but of depth, and probably, also, breadth; nevertheless, the shape and disposition of the constituent bones are such that, perhaps, no other known skull of a vertebrate is constructed with more economy of material—with an arrangement and connection of bones more completely adapted to combine lightness with strength.

So far as the skulls of *Pterosauria* have been sufficiently entire to show the shape of the head, no other known species resembles *Dimorphodon*. The cranial part is singularly small: the rest is mainly devoted to the formation of the large, long, and powerful prehensile and manducatory jaws. Among the débris of the cranial bones, in specimens Pls. XVII and XVIII, the mastoid (8), parts of the occipital (paroccipital, 4), the parietal (7), post-frontal (12), frontal (11), prefrontal (14), and nasal (15), are recognisable: the last two bones, however, are concerned more with the scaffolding or buttressing of the upper jaw than with the protection of the brain or formation of its case. Though contributing their shares to the otocrane, the chief developments of the paroccipital (Pl. XX, 4) and mastoid (ib. 8) relate to the muscular connections of the head with the trunk: the mastoid joins the postfrontal to form an upper zygoma, giving origin to part of the temporal muscles; it also affords a fixed articulation to the tympanic, and sends down a pointed process external to the masto-tympanic articulation. The parietals (Pl. XX, 7), confluent at the mid line, where they develop a low crest, swell out slightly at the temporal fossa, indicative of the size and saurian position of the mesencephalon. The frontal (11) is narrow and flat between the orbits, of which it contributes most of the upper part of the rim. This is continued by the postfrontal (12) behind, which sends down a long pointed process to unite with the malar (26), and a shorter and thicker one to join the mastoid (8). The prefrontal (14), of a triangular form, contributes to the upper and fore part of the orbit, and, either directly or by a connate lacrymal, unites with the ascending malo-maxillary process (21, 26), and the base of the prefrontal articulates with the frontal and the nasal. The nasals (15), to the usual connections with the frontal, prefrontal, and medial process of the premaxillary (22′), superadd a union with the lateral ascending process of the maxillary (21^{x}), completing the bar between the nostril (*n*) and the antorbital vacuity (*a*). The nasal bone forms the upper part of the nostril; the rest of the boundary of that singularly wide aperture is formed by the premaxillary and maxillary. Of the basis cranii and palate there do not appear to be any recognisable parts preserved. The maxillary is overlapped by the hind alveolar part of the premaxillary, and unites therewith by a long oblique suture ($21''$). The maxillary, receding, expands and sends upward a long slender pointed process to articulate

with the nasal; it then joins the malar and the prefronto-lacrymal, and descends internal to the mandible to join the palatine.[1] Each maxillary (21, 21′) affords alveoli for eight or nine teeth.

The premaxillary is the largest of the bones of the head. The pair, by confluence or connation, constitute the fore part of the upper jaw (22), expanding from a sub-obtuse apex as it recedes, and preserving its entireness for an extent of about two inches. This tract seems to be arched above transversely, with a slightly convex upper longitudinal contour continued along the medial ray or process (22′). Of the configuration of the palatal surface the specimens give no evidence. From the analogy of *Pterodactylus Cuvieri* and *Pt. Sedgwickii*,[2] we may infer that this (premaxillary) part of the bony roof of the mouth was entire, and strengthened by a median ridge. The lateral or alveolar borders formed alveoli for four teeth on each side. Thus the hind expansion of the premaxillary divides into three rays or processes. The upper medial or nasal ray is the longest: it is continued backward, continuing the initial curve of the upper contour of the face as far as the nasals, the mid suture or confluence of which bones it overlaps, and joins suturally to an extent precluding any movement of the upper jaw on that part of the head. The length of this ray is about $3\frac{1}{2}$ inches. The pair of lower or alveolar rays extend back for about $1\frac{1}{2}$ inches.

The malar (26) forms the lower narrower end of the oval orbit, sending up one pointed process (united with that of the maxillary ?) toward the prefrontal, and a longer and stronger one to join the postfrontal. The squamosal (27) continues the zygomatic bar backward to abut against the tympanic. Its precise position and direction are left doubtful in the specimens hitherto obtained, but it is unquestionably present, and contributes to the fixation of the tympanic.

This (28) is a moderately long and strong pedicle, immovably articulated to the mastoid, paroccipital, and squamosal; thickest posteriorly, where it is strengthened by an outer marginal ridge, sending forward and inward a process which may articulate with the pterygoid (but of this I could not get clear evidence), expanding at its distal end to receive the abutment of the squamosal or lower zygoma, and to form the convex condyle for the articular element of the mandible.

The dentary parts of the mandible are confluent at the symphysis, which is as long as the undivided fore part of the premaxillary. The ramal part of the dentary is compressed, and gains a depth of about 10 lines before it bifurcates. The alveolar border of the dentary extends as far as that of the maxillary, viz. about 5 inches, beyond which the upper prong (Pl. XX, 32′) is continued above the mandibular vacuity, underlapping the surangular (29) and terminating in a point. The lower prong (ib. 32″) terminates in a point before attaining the vacuity; it is underlapped by the fore part of the angular (30), with which it articulates.

[1] This description is on a homological hypothesis, subsequently discussed (p. 64).

[2] 'Monograph on Cretaceous Pterosauria,' Suppl. 1, 4to, 1859, Pl. I, fig. 1, *b*.

The divergence of the hinder prongs of the dentary exposes a small part of the splenial (31). The vacuity, if it be natural and not due to abrasion of a thin outer wall, is a long and narrow oval, 1 inch 8 lines in length, 6 lines in breadth. It is circumscribed behind by the confluent angular and surangular elements (29). The angular (30) forms a slight projection behind the articular concavity; it expands vertically, and contracts transversely as it advances, contributing a small share to the lower border of the vacuity, and contracting to a point below the dentary, about 5 inches from the angular process.

The range of variety shown by the skull is considerable in the order *Pterosauria*. In relative size, as in the expanse of the antorbital vacuity, *Pterodactylus crassirostris*[1] comes nearest to *Dimorphodon;* but the orbit is relatively larger, and the nostril much smaller. In *Rhamphorhynchus Gemmingi* the nostril and antorbital vacuity are of equal size, and each is about one eighth the size of the orbit, which is proportionally larger than in *Dimorphodon*. In *Pterodactylus longirostris*[2] the nostril is larger than the orbit; the antorbital vacuity is not half the size of the orbit. In *Pterodactylus suevicus*[3] the antorbital vacuity is still smaller. In *Pterodactylus Kochii*[4] that vacuity is limited, as in *Chlamydosaurus*, to the upper part of the boundary between the large orbit and the long and large nostril. In *Pterodactylus longicollum*[5] it appears to be wanting.

The shape of the skull offers many modifications in the several species, from the long and slender type of that of *Pterodactylus scolopaciceps* and *Pt. longirostris* to the shorter and deeper cone indicated by *Pt. conirostris*,[6] and to the inflated and more or less anteriorly obtuse form exhibited by *Dimorphodon* and the more gigantic *Pterodactylus simus*.[7]

The position of the tympanic pedicle varies from the almost vertical one in *Dimorphodon* to the almost horizontal one in *Pterodactylus longirostris* and *Pt. Kochii*. In *Pt. crassirostris* it shows an intermediate slope or position.

The mandible, conforming in relative depth and length to the general shape of the skull, has the symphysis longest in those species with long and slender jaws. In *Pterodactylus suevicus* the symphysis extends along the anterior third part of the mandible. In *Pt. crassirostris* it is shorter, and still shorter in *Dimorphodon*. The depth of the rami decreases behind the dentigerous part in *Pterodactylus longirostris*.

The generic dental character of *Dimorphodon* has been given in detail in the special descriptions of the specimens figured in Pls. XVII and XVIII. The range of variety mani-

[1] 'Monograph on Fossil Reptilia of the Cretaceous Formations' (1851), *Pterosauria*, Pl. XXVII, figs. 2—4.

[2] Ib., ib., fig. 1.

[3] Quenstedt, op. cit.

[4] Von Meyer, op. cit., tab. i, fig. 2.

[5] Ib., ib., tab. vii, figs. 1—4.

[6] Dixon's 'Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex, 4to, 1846, Pl. 38.

[7] 'Monograph on Fossil Reptilia of the Cretaceous Formations' (*Pterosauria*), Suppl. No. 3 (1861), Pl. I, figs. 1—3.

fested in this character is considerable in the present order, although in no species has any departure been observed from the predatory zoophagous condition. The teeth, always simple and pointed, vary in shape, in number, in position, in relative size. *Pterodactylus crassirostris* exemplifies the laniariform type of teeth, more or less elongate, and separated by intervals of varying extent. In this not uncommon condition the teeth are longest in the upper jaw, as offering more resistance than does the lower jaw in aid of the weapons most deeply implanted in the struggling prey.

In *Pterodactylus longirostris* the teeth are rather small, subequal, with short intervals, a little widening toward the hind end of the series, which is restricted to the anterior half of the jaw, both above and below.

In some *Pterosauria* a certain extent of the fore part of both upper and under jaws is edentulous, and from its shape has been inferred to have supported a horny sheath. The teeth are long slender canines, with wide intervals. They number from about 8 to 10 on each side of the upper jaw, and from 7 to 8 in each ramus of the mandible. Von Meyer proposed for this modification of mouth the generic name *Rhamphorhynchus*.

Dimorphodon shows the combination of scattered laniaries, with small, more closely set serial teeth in the lower jaw; it has more numerous teeth, occupying a greater extent of the alveolar margins of the jaws, than in any other Pterosaurian.

The very small teeth which have been observed in the short jaws of the little *Pterodactylus brevirostris*[1] are most probably characters of immaturity, not of species.

In regard to the bony structure of the head and the dentition, the general result of observation and comparison of Pterosaurian fossils, and common consent of competent investigators, having excluded the volant Mammals from the claim of affinity, the question becomes narrowed to whether the skull in *Pterosauria* more resembles that in the cold-blooded or the warm-blooded oviparous air-breathing Vertebrates.

Hermann von Meyer, who has contributed a great and valuable share to our knowledge of the Pterosaurian order,[2] quoting Oken's opinion, "that the skull is intermediate in character between that of the Chameleon and Crocodile," sums up his own conclusions on that head in the following terms:—"The skull of *Pterodactylus* is essentially comparable only with that of Birds and Saurians. The preponderating resemblance with the Bird's skull cannot be contested. Against this, however, is a remarkable dissimilarity in certain parts which, on the other hand, approximates it to the type of Saurians."[3]

The term *Sauria* is here used in the sense of Brongniart and Cuvier, and it is open

[1] Goldfuss, loc. cit., tab. x, fig. 2.

[2] Especially in the admirable summary of his own and others' researches, in the part of his great work, 'Zur Fauna der Vorwelt' relating to "Reptilien aus dem lithographischen Schiefer," &c., fol., 1860.

[3] "Der Schädel der Pterodactyln, der nach Oken zwischen Chamäleon und Crocodil stehen würde, lässt sich eigentlich nur mit den Vögeln und den Sauriern vergleichen; die überwiegende Aehnlichkeit mit dem Vogelkopfe kann nicht bestritten werden; ihr gegenüber steht aber eine auffallende Unähnlichkeit in gewissen Theilen, die dafür zum Zypus der Saurier hinneigen."—Op. cit., p. 15.

to the unbiassed investigator, and, indeed, becomes plainly his business, to determine, not merely whether Avian or Saurian characters predominate in the Pterosaurian skull, but to define the degree of affinity or correspondence of cranial structure therein traceable to such structures in *Enaliosauria*, *Dinosauria*, *Dicynodontia*, *Crocodilia*, *Lacertilia*, each of which may be a group, organically, of co-ordinate value with *Aves*.

Greater respect to the memory of so unbiassed a seeker after truth cannot be shown than by weighing with due care and what judgment one may be able to bring to the task the value and significance of each well-determined evidence of the cranial structure which Von Meyer has described and reasoned upon.

It is to be regretted that not in any of the numerous figures of the skull of *Pterosauria*, original or copied, has Von Meyer indicated the bones which he describes. When he writes—"The temporal bone lies external to the parietal and principal frontal bones, and mainly forms the temporal fossa,"[1] one much wishes he had indicated his 'Schläfenbein' in the skull of *Rhamphorhynchus Gemmingi*, pl. iii, fig. 4; pl. ix; pl. x, fig. 1; or in the more instructive example of cranial structure which he has borrowed from Goldfuss for the subject of his pl. v (*Pterodactylus crassirostris*).

By 'Schläfenbein' Von Meyer may mean that element of the compound 'temporal bone' of anthropotomy which I have called 'squamosal.' No doubt in Man and most Mammals the squamosal does contribute a notable share to the formation of the temporal fossa, whence the name 'temporal' given to the incongruous group of cranial elements coalescing in such warm-blooded Vertebrates with the squamosal, so exceptionally expanded in the *Mammalia*. But as to the value of the bed of the temporal muscles in determining the homology of the bones forming it, I would refer to the remarks in my work on the 'Homologies of the Vertebrate Skeleton.'[2]

Some clue to the bone signified by Von Meyer may be got from the following remarks—"Anteriorly it seems not to take, as in Birds, a share in the formation of the orbital rim; here, much more as in Saurians, it is pushed aside or supplanted by the postfrontal."[3]

The term 'temporal bone' (Schläfenbein) has been used in various senses, but whether it be applied to that element which I, with Cuvier, call 'mastoid' in *Reptilia*, or to that which others,[4] with Cuvier, call 'temporal' (meaning squamosal) in Birds, there is no bone that Von Meyer can be supposed to mean by 'Schläfenbein' which forms any part of the rim of the orbit in Birds.

Von Meyer recognises a 'postfrontal' ('Hinterstirnbein') in *Pterosauria*, and states that it pushes away his temporal (Schläfenbein) from the orbit. In *Pterosauria* the post-

[1] "Das Schläfenbein liegt aussen an dem Scheitelbein und Hauptstirnbein, und bildet hauptsächlich die Schläfengrube."—Op. cit., p. 15.

[2] 8vo, 1848, p. 33.

[3] "Vorn scheint es nicht wie in den Vögeln an der Bildung des Augenhöhlenrandes Theil zu nehmen, hier vielmehr wie in den Sauriern durch das Hinterstirnbein verdrängt zu werden."—Op. cit. p. 15.

[4] Hallman, "Die vergleichende Osteologie des Schläfenbeins," p. 8, pl. 1.

frontal (Pl. XX, 12) is undoubtedly interposed between the bone I determine as 'mastoid' (ib. 8) and the orbit (ib. *o*); and my 'mastoid' in *Pterosauria* answers to Cuvier's and Hallman's 'temporal,' *i.e.* squamosal, in Birds. We may conclude, therefore, that Von Meyer's 'Schläfenbein' in *Pterosauria* is that marked 8 in the skull of *Pterodactylus crassirostris*.[1]

Certain it is that no bone answering to 8 in Pls. XVII, XVIII, XX of the present Monograph contributes to the formation of the orbit in any Bird. In the great majority of that class, as is well known, the rim of the orbit is incomplete below; it is formed above by the frontal, before by the prefrontal and lacrymal ('antorbital' of ornithotomists), behind by the postfrontal ('postorbital,' ib.). Where, as in some *Psittacidæ*,[2] the orbital rim ('Augenhöhlenrandes') is complete, the lower complement is formed by an extension of ossification from the antorbital to the postorbital processes, independently of either Cuvier's temporal (8) or my squamosal (27) in Birds.

I confess that the foregoing result of the analysis of a main ground of Von Meyer's assertion as to the "incontestable similarity between the Pterosaurian and Avian types of cranial structure" has not a little tended to shake my confidence in the grounds on which he has pronounced definite judgment on the matter. So far as we have yet got evidence of the structure of the skull in *Pterosauria*, it seems that, contrary to the rule in Birds, the orbital rim is entire; and that its lower border is completed by the zygomatic arch, and chiefly, if not exclusively, by the malar element; whereas, such arch passes freely beneath the orbital rim in the few Birds with that rim entire. Now, in this part of the cranial structure the *Pterosauria* agree with the *Crocodilia*: as in them the malar (26) sends up a process to unite with one descending from the postfrontal (12) to complete the orbital rim behind.

In the small species of Pterodactyles (*Pt. longirostris*, *Pt. scolopaciceps*, and in the perhaps immature animal represented by *Pt. brevirostris*) the hind convexity of the cranial wall is not marked by the apophysiary developments of paroccipital and mastoid, and accordingly resembles that part of the cranium in Birds, especially the smaller *Grallæ*; but before this similarity of shape can be pressed into the argument for the Avian affinity of the *Pterosauria*, it should be shown to be common to or constant in the extinct volant order.

But this is far from being the case. When a Pterosaur has gained the size of *Pterodactylus crassirostris*[3] or *Pter. suevicus*,[4] the back of the skull shows no cerebral swelling, but only the crests and processes for muscular attachments, as in other *Reptilia*

[1] 'Monograph on Fossil Reptilia of the Cretaceous Formations' (*Pterosauria*) (1851),' Pl. XXVII, figs. 3 and 4.

[2] 'On the Archetype and Homologies of the Vertebrate Skeleton,' 8vo, 1848, pl. i, fig. 1 (*Calyptorhynchus*); 'Anatomy of Vertebrates,' 8vo, vol. ii (1866), p. 51, fig. 30 (*Psittacus*), also p. 63.

[3] Goldfuss, op. cit., pl. vii.

[4] Quenstedt, op. cit.

of similar size. Even in *Rhamphorhynchus Gemmingi* the cranial convexity is not posterior, but is limited to the temporal fossæ behind the orbit, as in the specimen figured by Von Meyer in pl. ix, op. cit.; and this indication of the optic lobes is less conspicuous in the subject of pl. x, fig. 1. In *Dimorphodon* there is still less trace of this alleged Avian characteristic.

The bone which, in the Bird, as in the Pterosaur, forms part of the otocrane, articulates with the ex- and par-occipitals behind, with the alisphenoid in front, with the parietal above, and with the petrosal within, which contributes the articular surface to the tympanic and the upper rim to the meatus auditorius, also articulates in the Pterosaur, as in the Crocodile, with the postfrontal: and this character appears to be constant in the *Pterosauria* as in the *Crocodilia*, while it is exceptional in *Aves*. In the particulars in which the bone 8 differs in the *Pterosaurian* from that in the Bird, it agrees with 8 in *Crocodilia*; as *e.g.* in its high position in the cranium, owing to the low development of the cranial chamber; its greater degree of projection from the true cranial walls; the extensive and suturally fixed character of its articulation with the tympanic as compared with the more definite and restricted glenoidal movable articulation which the mastoid (8) affords to 28 in Birds. In all these circumstances, whether the bone 8 (Pl. XX, fig. 1) be called mastoid or squamosal, it is Reptilian, not Avian, in the Pterosaur.

Herr Von Meyer states, in another of his comparisons, that in the *Monitor*, *Iguana*, and *Stellio*, the prefrontal ('Vorderstirnbein') enters into the formation of the periphery of the external nostril (Nasenloch).[1] This is the case with *Varanus*,[2] not with true Monitors.[3] In *Tejus nigropunctatus* some extent of the suture between the nasal and the maxillary intervenes between the prefrontal and the nostril. The non-extension of the prefrontal to the external nostril shows no Avian affinity in *Pterosauria*; rather an agreement with the majority of *Reptilia*, as, for example, with the whole order of *Crocodilia*.

In some *Crocodilia* (*Teleosaurus*) and *Lacertilia* (*Chlamydosaurus*, *Lyriocephalus*) there is an antorbital vacuity, which, in the latter Lizard (Pl. XX, fig. 3, *a*), is equal in size with the nostril (ib., *n*) and intermediate in position between that cavity and the orbit (ib., *o*), which is large. A process of the maxillary rises obliquely backward to join the nasal, and to separate the intermediate vacuity from the external nostril. The lacrymal and prefrontal form the bar dividing the intermediate cavities from the orbit. In most Birds a small intermediate vacuity is partitioned off from the nostril by a process of the maxillary rising to join the nasal, and is similarly separated from the orbit by the lacrymal, which descends to join the malar. The great range of variety in the development of this 'intermediate' or 'antorbital vacuity,' in *Pterosauria*, has already been pointed out; but

[1] 'Zur Fauna der Vorwelt,' fol., 1860, p. 16.

[2] See Cuvier, 'Ossemens fossiles,' v, pt. 2, pl. xvi, fig. 1 ('grand Monitor du Nil, *Lacerta nilotica*'), p. 259, the *Varanus Dracæna* of Merrem, *Varanus niloticus* of most modern erpetologists; also in pl. xvi, fig. 7, 'Monitor du Java,' p. 260; the *Varanus bivittatus*, of Merrem.

[3] As *e.g. Tupinambis teguixin*, 'Sauve-garde d'Amérique.' Cuvier, vol. cit., pl. xvi, figs. 10, 11, and *Thorictes Dracæna*, ib., figs. 12, 13; 'La Dragone,' ib., p. 263.

the comparable structure is by no means peculiar, as Von Meyer would lead one to infer, to the skulls of Birds.[1]

In no Pterosaurian has any obvious and unmistakeable suture been seen indicative of the respective shares taken by maxillary (21) and premaxillary (22) in the formation of the dentigerous part of the upper jaw: both bones combine to support the array of teeth; they have coalesced, at least at their external or faci-alveolar plates; as, likewise, have the right and left premaxillary portions forming the fore end of the upper jaw. The suture between this premaxillo-maxillary bone and the suborbital portion of the zygomatic arch remains. Accordingly, there is a choice of analogies in the interpretation of the observed facts: a proportion of the compound bone may be assigned to the premaxillary, according to the analogy of the Crocodile and Lizard; or the whole may be called premaxillary, according to the analogy of the Ichthyosaur.

Goldfuss, guided by the Lacertian analogy, limits the premaxillary to the anterior part of the upper jaw, and to the upper part of the external bony nostril (*n*); and he illustrates this view by a dotted line representing the assumed suture in his restoration of *Pterodactylus crassirostris*, in pl. ix (op. cit.).[2] Von Meyer assumes, as arbitrarily, the Ichthyosaurian analogy, but views it as a specially Avian one, and ascribes to the *Pterosauria* a bird-like premaxillary,[3] and this determination is indicated by the numerals on the restoration of the skull of *Pterodactylus compressirostris* in my Monograph of 1851, quoted below, Pl. XXVII, fig. 5.

Of the maxillary bone (my 21) Von Meyer merely remarks that "it does not follow the type of Birds" ("folgen nicht dem Typus der Vögel," ib., p. 15). And yet, if the Pterosaurian premaxillary be interpreted according to that type, forming so large a proportion of the upper jaw as to include all the teeth, the edentulous maxillary must have had a correspondingly Avian proportion and position. Only, whereas in most Birds the small and slender maxillary sends up a process helping to define the back part of the nostril and fore part of the antorbital vacuity, the corresponding process in *Pterosauria* would be (as indicated in my Pl. XVIII, 22^{x}), part of the premaxillary.

I incline to believe, however, that it may prove to belong to the maxillary; that the dentigerous part of the upper jaw is due, in *Pterosauria*, to the combined maxillaries and premaxillaries, but that the latter take a larger share in the formation of the alveolar tract than Goldfuss conjectures. One ground of such opinion is this: the portion of upper jaw with six pairs of laniary teeth in the huge *Pterodactylus Sedgwickii*, in which the palatal surface could be clearly worked out,[4] showed that the anterior expansion, with the group of three pairs of teeth, could hardly have been

[1] "Zwischen Nasenloch und Augenhöhle liegt eine dritte Oeffnung, die wiederum an den Vögelschädel erinnert."—Op. cit., p. 16.

[2] Copied in Pl. XXVII, fig. 4, of my Monograph above cited of 1851.

[3] "Ein Vögeln-ähnlichen Zwischenkiefers," v, p. 15, op. cit.

[4] Monograph, Suppl. No. 1 (1859), Pl. I, figs. 1, *a*, *b*.

separated by a suture, at the slight constriction suggesting that structure in *Pt. crassirostris*,[1] without leaving some indication of its original existence, especially on the palate.

In the anterior confluence of right and left premaxillaries, and the backward production from their upper part of a bony bar uniting with the nasals and dividing the nostrils, we have a character of the Dicynodonts and of some Lacertians (*Varanus*) as well as of Birds, and the Saurian affinity is shown to be the truer one by the firmness of the naso-premaxillary union and the absence of any power of, or provision for, that hinge-like movement of the upper mandible upon the cranium which is peculiar to, though not constant in, the Avian class. Moreover, the outer surface of the premaxillary shows none of that spongy porosity and rugosity which relates to the sheath or horny covering of the beak characteristic of the Bird. Such structure has not even been detected in the feeble trace of edentulous anterior production of the upper jaw in *Rhamphorhynchus*, Von Meyer. I cannot, therefore, see, with Von Meyer, the beak of the Bird in an animal with a fixed and toothed upper jaw ;[2] for on every hypothesis of its bony structure it finds a closer resemblance among the toothed Reptiles than in the class of Birds.

The mandible, or lower jaw, is supported, as in all Vertebrates below Mammals, by the tympanic, viz. the bone (28, Pls. XVIII and XX) which is shown by its osseous connections, its relations to the 'facial nerve,'[3] or its equivalent the 'ramus opercularis,'[4] and by its mode of formation, to answer to that which in Mammals is mainly reduced to the function of supporting the ear-drum. In air-breathing Ovipara it superadds this function to its more constant and essential use in non-mammalian Vertebrates, of supporting the lower jaw.

In reference to the question of affinity before us, the tympanic gives valuable evidence by reason of the moveable articulation and peculiar connections with the upper mandible essentially correlated to a covering of feathers. In *Pterosauria* the tympanic at its proximal end resembles that of Lizards by its fixed sutural mode of union with the cranium, and it furthermore resembles that in Crocodiles by the abutment of the zygoma against its distal end, to which it is suturally attached.

In Birds the tympanic enjoys a synovial moveable articulation by a single or double condyle at its proximal or cranial end, and presents a synovial cavity to a condyloid convexity of the hind part of the zygoma. By this test, therefore, the *Pterosauria* are shown to be not only 'Saurian,' but to be nearest akin to the existing orders which possess double-jointed ribs and the correlated cardiac structure. The difference of shape between the tympanic of the Pterodactyle and that of the Bird is too strongly marked not to have attracted attention; but I do not find in that of the Chameleon the

[1] Goldfuss, loc. cit.

[2] "Wir sehen also hier die Schnautze der Vögel auf ein Thier mit unbeweglicher und mit Zähnen bewaffneten Schnautze angewendet."—Op. cit., p. 15.

[3] 'Anatomy of Vertebrates,' vol. ii, 8vo, 1866, p. 124, vol. iii, p. 155.

[4] Ib., vol. i, p. 303.

most resemblance to the *Pterosaurian* tympanic.[1] For, besides the Lacertian freedom of the bone from zygomatic abutment, the tympanic in the Chameleon has not the longitudinal strengthening ridges, nor the process turned toward the pterygoid.

The dentigerous mandible, like the maxilla, speaks for the Reptilian affinity of *Pterosauria;* the distinct sockets for the teeth ally them to the higher forms of *Sauria.* In reference to the generic modification of dentition in *Dimorphodon,* it has been remarked that this early form of flying dragon seemed to have derived one feature or modification from the Fish, and the other from the Crocodile or Plesiosaur.[2]

The length of the neck, which is not always equal to that of the head, is due, in *Pterosauria,* rather to the length than the number of the vertebræ. Counting the axis with the small coalesced atlas[3] as one, I give seven cervical vertebræ to the *Dimorphodon macronyx* (Pl. XX, fig. 1, c). Of these a series of four are preserved in the specimen (Pl. XVIII, c), showing, as described, the characteristics of the Pterosaurian cervical vertebræ which had been determined and illustrated in a former Monograph.[4]

Cuvier,[5] in his searching analysis of the evidence at his command of the osseous structure of the *Pterodactylus longirostris,* concluded that the cervical vertebræ were not fewer than seven, as in *Crocodilia* and *Mammalia,* or not more than eight, as in *Chelonia.*

Goldfuss was able to demonstrate the vertebral formula in his famous specimen of *Pterodactylus crassirostris.*[6] The number, 'seven,' was, however, obtained by reckoning the atlas distinct from the axis, and the last cervical may have been relegated to the dorsal series.

Quenstedt[7] shows seven cervicals in his instructive example of *Pterodactylus suevicus,* reckoning the atlas and axis as one vertebra; and this analogy I have followed in the restoration of *Dimorphodon.*

Rhamphorhynchus Gemmingi has six cervicals, counting the coalesced atlas and axis as one; but in the specimen figured by Von Meyer in his pl. ix,[8] there seems to be the centrum of a short 'seventh' cervical between the longer 'sixth' and the first (dorsal) vertebra supporting a long free pointed rib. It is certain that the number of cervicals does not exceed the latter reckoning or fall short of the first. Thus it is plain that the *Pterosauria* exemplify the Crocodilian affinity in the cervical region of the vertebral column. Lacer-

[1] "Dieser Knochen ist nicht wie in den Vögeln quadratisch, sondern cylindrisch stielförmig beschaffem.—Hierin, so wie in einingen andern Theilen, zeigt das Thier die meiste Aehnlichkeit mit *Chamaeleon.*"—Von Meyer, op. cit., p. 16.

[2] 'Report (Sections) of the British Association for the Advancement of Science,' 8vo, 1858, p. 98.

[3] 'Monograph on the Fossil Reptilia of the Cretaceous Formations,' Supplement, No. I, *Pterosauria* (1859), pp. 7—8, Pl. I, figs. 11—14.

[4] Ib., p. 9—11, Pl. II. 'Monograph,' &c., Supplement, No. III (1860), p. 7, Pl. II, figs. 1, 2 and 4.

[5] 'Ossemens fossiles,' tom. cit., p. 367.

[6] "Man zählt 7 Halswirbel, 15 Rippenwirbel, 2 Lenden, and 2 Kreuzbeinwirbel," loc. cit., p. 79.

[7] Op. cit., figs. 1—7.

[8] Op. cit.

tians have fewer definite cervicals ; Birds have more. I have not seen any Bird with fewer than eleven cervicals.[1] The length and flexibility of the neck is correlated with the covering necessitated by the high temperature of the Bird.[2] The cold-blooded flying Reptiles have a comparatively short and rigid neck, but of a thickness and strength proportionate to the size of the head, and adequate to the work to be performed by the jaws in overcoming and bearing away the prey they may have seized.

The chief variety manifested by the *Pterosauria* in the cervical region is in the relative length of the last six vertebræ; this is greatest in *Pterodactylus longicollum* and *Pt. longirostris;* it is least in *Pt. crassirostris* and *Dimorphodon macronyx*, and apparently also in *Pterodactylus simus*, if we may judge by the breadth, compared with the length, of the vertebra figured in Pl. XVIII, (figs. 1 and 2) of my Monograph, above cited, of 1860.

There seems to have prevailed a greater range of variety in the number of vertebræ between the cervical series and the sacrum. In *Pterodactylus longirostris*, Cuvier estimated at least twelve which supported moveable ribs,[3] and nineteen or twenty in the dorso-lumbar series. Von Meyer concluded that the number of dorsal vertebræ fell not below twelve in any species, nor exceeded fifteen or sixteen in *Pterosauria*. *Pterodactylus Kochii* shows fourteen dorsal vertebræ; *Pt. crassirostris* not more than twelve, reckoned by the number of pairs of free ribs, which can be satisfactorily discerned.

I have seen no specimen of *Dimorphodon* yielding definitely the number of the dorso-lumbar vertebræ, *i. e.* of the vertebræ between the cervical and sacral; it is from the best considerations I have been able to give to the analogies of these vertebral formulæ, in better preserved examples of other species of *Pterosauria*, that I assign thirteen to this series in my restoration of *Dimorphodon macronyx* (Pl. XX); and I conclude that the thirteenth was a true lumbar vertebra or without connection with a free pair of ribs. If there should prove to be error in this estimate I cannot think it will extend beyond one vertebra, or at most two, in excess of twelve dorsals.

The nine dorsal vertebræ, which have kept together, in almost a straight line, in the specimen (Pl. XVIII, D), testify to the strength and closeness of their reciprocal articulations, under disturbing influences which have affected so great and general a degree of dislocation of most other parts of the skeleton.

Buckland seems first to have observed the convexity of one of the terminal articular surfaces of the centrum of a dorsal vertebra, and to have deduced an affinity therefrom;

[1] The Sparrow (*Pyrgita domestica*) has twelve ('Osteol. Catal. Coll. of Surgeons,' No. 1571, vol. i, p. 297).

[2] "As the prehensile functions of the hand are transferred to the beak, so those of the arm are performed by the neck of the Bird; that portion of the spine is, therefore, composed of numerous, elongated, and freely moveable vertebræ, and is never so short or so rigid but that it can be made to apply the beak to the coccygeal oil-gland, and to every part of the body, for the purpose of oiling and cleansing the plumage." —'*Anat. of Vertebrates*,' ii, p. 39.

[3] Vol. cit., p. 368 :—"Il semble qu'il en est resté au moins douze en place du coté gauche." The specimen figured by Von Meyer, op. cit. in pl. i, fig. 1, shows thirteen ribs on the left side of the trunk.

(the specimen is marked *d* in the Plate 27 of his Memoir, loc. cit.), and is described "as the body of a vertebra showing a convex articulating surface, as in the Crocodile" (p. 221). Quenstedt's *Pterodactylus suevicus* showed similar detached dorsals, in one of which it appeared that "the articular surfaces of the body were convex at the back end, and concave at the fore part."[1] Buckland's specimen serves to dissipate any doubt on the point so important in reference to the Crocodilian affinity. It might be assumed that the Author viewed the convexity as posterior by the expression "as in the Crocodile;" and in the last of the dorso-lumbar series, which I regard, with Buckland, as 'probably lumbar,' in the sense of not being costigerous, the position of "its concave articulating surface" is demonstrated by those of the articular processes (zygapophyses) at the same end of the vertebra, which prove them to be the anterior pair, slightly prominent, looking upward and inward. Buckland notes these as "two anterior spinous processes, an obvious typographical error for 'oblique' or 'articular,' venial in one not professedly an anatomist.[2]

With regard to the Crocodilian affinity inferred from this structure, it must be remembered that the procœlian stucture, though it has been observed in Crocodiles from the Greensand of New Jersey,[3] is characteristic of the Tertiary and existing species, rather than of the order at large, which had more abundant and diversified (amphicœlian and opisthocœlian) representatives in the Secondary ages of Geology. Moreover, the anterior concavity and posterior convexity of the vertebral body obtain in most recent, Tertiary, and Cretaceous *Lacertilia;* and finally, the cup- and ball-joints of the centrum appear in the dorsal vertebræ of at least one genus of Birds, though with the ball in front.[4]

In the series of nine dorsals, preserved in the subject of Pl. XVIII, d, the centrums slightly lose length as they recede in position from the neck; the anterior ones measure 0·009 mm. = 4½ lines; the posterior ones measure 0·008 mm. = 4 lines; the transverse diameter of the articular ends is 0·007 mm. = 3 lines. The dorsal vertebra in Buckland's specimen presents the same dimensions. These dimensions increase as the two or three anterior dorsals approach the neck, but the greater enlargement of the last cervical is somewhat abrupt.

For the shape and proportions of the ribs (in the Restoration, Pl. XX), I have those marked *b*, *c* in the original specimen,[5] and the more numerous and better preserved ones

[1] "Die Gelenkfläche der Wirbelkörper war auf der Hinterseite convex, wie beim Crokodil, vorn dagegen concav. So scheint es wenigstens."—Quenstedt, Ueber *Pterodactylus suevicus* im lithographischen Schiefer Würtembergs. 4to, 1855, p. 45.

[2] Buckland, loc. cit., pl. 27. [This vertebra is shown in Pl. III, fig. 2, of the present Monograph.]

[3] "Notes on Remains of Fossil Reptiles discovered in the Greensand Formations of New Jersey," 'Quarterly Journal of the Geological Society,' vol. v, 1849, p. 388.

[4] As in *Aptenodytes;* "On the Vertebral Characters of the Order *Pterosauria*," 'Phil. Trans.,' 1849, pl. x, fig. 22, p. 163.

[5] Buckland, loc. cit., pl. 27.

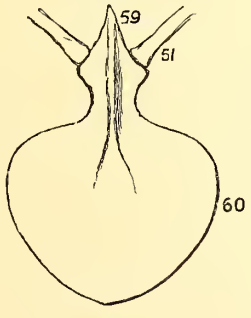
in the specimen figured in Pl. XVIII. Their articulations with the vertebræ have already been noticed. The ribs increase in length to the fifth or sixth, with some diminution of breadth after the third, and acquire a characteristic tenuity beyond the sixth pair. On the outer surface a groove extends from the neck, or interspace between the head and tubercle downward; the front border of the groove being somewhat prominent, but subsiding in the hinder ribs. Epipleural appendages are indicated in some specimens; but the indications are feeble, and, if rightly so interpreted, these appendages seem to have been but partially ossified.

The sternal ribs, beyond the sternum, unite below with the free ends of the abdominal V-shaped, intermuscular styles.

The irregular elongate mass (marked 18 in pl. xxviii of Buckland's Memoir) and conjectured to be "sternum—much broken, and its form indistinct" (loc. cit., p. 221) includes two crushed cervical vertebræ, and part of a third. Of the sternum I have not been able to discern a satisfactory trace in any of the specimens of *Dimorphodon;* its proportions and position are, therefore, indicated in the 'restoration' (Pl. XX) according to the analogy of that in *Pterodactylus suevicus*,[1] *Pt. simus*,[2] and in *Rhamphorhynchus*.[3]

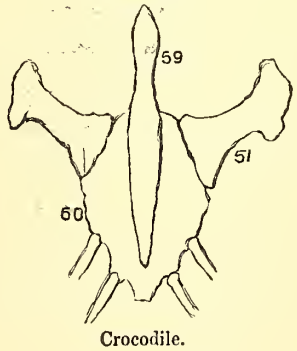
In the main, as regards breadth of the hind part and depth of the fore part, the breast-bone of *Pterosauria* is formed on the Ornithic pattern; *i. e.* it is shield-shaped, and it has a keel. But the keel does not descend from the expanded portion; it is formed, as shown in a former Monograph (Suppl. No. III, p. 8), by the vertical development of the anterior production answering to the ossified sternum of Crocodiles and to the episternum of Lizards. I would recommend a comparison of the figures of the sternum in *Iguana* and *Notornis*, given at p. 21, vol. iii, of my 'Anatomy of Vertebrates,' to whosoever may desire to form an opinion of the evidence of affinity to Birds or to Reptiles, respectively,

Fig. 1.



Pterosaur.

Fig. 2.



Crocodile.

afforded by the Pterosaurian sternum, especially as this is illustrated in figures 7 to 12 of Pl. II of the Supplement No. III, above cited. No one desirous of simply getting at the

[1] Quenstedt, loc. cit. (1855).

[2] 'Monograph,' Suppl., No. III (1860), Pl. II, figs. 7—12.

[3] Von Meyer, op. cit. (1860), pl. vii, figs. 1 and 3, and pl. ix, fig. 1.

truth of the matter can put aside the 'post-coracoid lateral emarginations,' and other modifications defined in that Monograph as 'distinctive Pterosaurian characters.' No Bird has shown any approach to them. What modifications of the Pterosaurian sternum *Dimorphodon* may have presented, we have yet to learn.

In all cases in which it has been observed, the sternum in *Pterosauria* (fig. 1) resembles in essential characters that of *Crocodilia* (fig. 2); its chief part is a longitudinal, compressed, deep bar (59), expanding laterally, some way from the fore-end, for the articulation of the coracoids (51),[1] and having the posterior expansion (60), which remains cartilaginous in the *Crocodilia*, more or less ossified, in the form of a thin semicircular plate: but the whole bone, though adaptively modified for attachment of muscles of flight, preserves the characteristic shortness compared with the trunk, and offers a striking contrast to the long and large subabdominal plastron in most birds of flight. There is no distinct T-shaped episternum, such as exists in most *Lacertia*, and no trace of clavicles as in Lizards and Birds. Distinct lateral elements for articulation with sternal ribs I have not satisfactorily made out in any specimen.

The abdominal hæmal arches consist of slender hæmapophyses and of chevron-shaped hæmal spines.

There is evidence of one lumbar or ribless vertebra anterior to the sacrum, in *Dimorphodon;* and no Pterosaurian appears to have shown more than two such vertebræ: in this character we are again directed to the true Reptilian relation of *Pterosauria*, and warned off the beguiling marks of Avian affinity.

The indications of epipleural appendages of ribs, more or less bony, if rightly interpreted, answer to the gristly ones in *Crocodilia* and some *Lacertia*.[2] The restoration of the bony cage of the thoracic-abdominal cavity of *Dimorphodon* (Pl. XX) is based on the analogy of better preserved specimens of *Pterosauria* in regard to this part of the skeleton. Scattered elements of the hæmal arches, 'abdominal ribs,' &c., have alone been met with in the specimens of *Dimorphodon* hitherto obtained.

The sacrum, on the probable hypothesis of retention of the length of centrum shown in the lumbar vertebra, would include at least four vertebræ; if, as by the analogy of the sacrum (figured in Pl. II, fig. 26, of the Monograph, &c., Supplement No. 1, 1859), the vertebræ lost length at this confluent tract, there might be five or six sacrals articulating with the iliac bones in *Dimorphodon*. Von Meyer figures 5—6 anchylosed sacral vertebræ in his *Pterodactylus dubius;*[3] and the sacrum appears to consist of at least six confluent vertebræ in *Rhamphorhynchus grandipelvis*, Von Meyer.[4]

With all the evidence that the *Pterosauria*, like the *Dinosauria* and *Dicynodontia*,

[1] 'Monograph on Cretaceous Reptilia,' Supplement, No. III (1860), Pl. II, figs. 7—12.

[2] As in *Hatteria*, see Günther's excellent Memoir, in 'Philos. Trans.,' Part II, 1867, p. 13, pl. ii, figs. 17, 24.

[3] Op. cit., p. 17, pl. vi, fig. 1.

[4] Op. cit., p. 53, pl. viii, fig. 1.

exceeded the sacral formula prevailing in existing *Crocodilia* and *Lacertilia*, we should gain no firm ground therefrom for predicating Avian affinity or for building thereon a derivative hypothesis of the class of Birds. Many existing Chelonian Reptiles have a sacrum composed of more than two vertebræ.[1]

The perfect specimen of tail-vertebræ and associated bone-tendons in the specimen (Pl. XIX, fig. 4) completes satisfactorily the restoration of this part of the vertebral column in *Dimorphodon*. Before the discovery of *Rhamphorhynchus*, the order *Pterosauria* was known only through species having the tail very short. Not only were the vertebræ comparatively few, estimated at twelve or thirteen in *Pterodactylus longirostris*,[2] at fourteen in *Pt. spectabilis*, at fifteen in *Pt. scolopaciceps*,[3] and as low as ten in *Pt. Meyeri*,[4] but they were very small and short. The great advocate of the Avian affinity of the Pterosaurs, Soemmerring, based his chief argument in this character. But Cuvier was able to adduce instances of *Reptilia* with tails as short; and he might now have cited a Bird with a tail-skeleton as long, as slender, and as many-jointed as in divers Saurians.[5] The earliest indication of a range of variety in this part of the bony framework of a Pterosaur was deduced, with his usual sagacity, by Buckland.

In the original specimen of *Dimorphodon* are three caudal vertebræ at the base of the tail, marked K, in pl. xxvii of his Memoir, from the size of which vertebræ, together with the larger and longer legs, as compared with *Pterodactylus longirostris*, Buckland inferred that the entire "tail was probably longer, and may have co-operated with the legs in expanding the membrane for flight."[6] "A long and powerful tail," he proceeds to remark, "is in strict conformity with the character of a Lizard" (ib.).[7]

Buckland would have had further direct confirmation of the length and strength of the tail of his Lias Pterosaur, if he had recognised the series preserved at *a*, *a'*, in his pl. xxvii, as caudal vertebræ; but they were conceived to belong to the neck, notwithstanding their slenderness and length, and that around them were "small cylindrical bony tendons, resembling the soft tendons that run parallel to the vertebræ in the tails of Rats."[8] When the evidences of caudal structure were first recognised by Von Meyer, in *Rhamphorhynchus Gemmingi*, he detected the homologous structures in pl. xxvii of

[1] 'Anat. of Vertebrates,' vol. i, p. 65.

[2] By Cuvier, vol. cit., p. 368.

[3] Von Meyer, op. cit., p. 17.

[4] Ib., p. 17.

[5] Owen "On the *Archæopteryx*," 'Philos. Trans.,' 1863, p. 33, pls. i—iv.

[6] Buckland, loc. cit., p. 221.

[7] *Archæopteryx* had not then been discovered; else, it might have been objected to the above hint of affinity, not only that there had been short-tailed Pterodactyles, but also long-tailed Birds.

[8] "Mr. Clift and Mr. Broderip have discovered that the remaining cervical vertebræ are surrounded with small cylindrical bony tendons of the size of a thread. These run parallel to the vertebræ, like the tendons that surround the tails of rats, and resemble the bony tendons that run along the back of the pigmy musk and of many birds" (loc. cit., p. 218).

Buckland's Memoir, and suggested that its subject might belong to the same section or genus.[1] The subsequent discovery of the skull and dentition has, however, shown that another generic section of *Pterosauria*, or at least one species thereof, had a similar long and stiff tail. The modification involving that quality does not, however, extend throughout; the anterior caudal vertebræ retain the more normal character, and the appendage would be most moveable at its base. No doubt a small degree of yielding at the many persistent vertebral joints—for complete anchylosis has not been observed—would allow a slight curvature to the extent to which the tail is represented as yielding to a lateral force in the restored figure (Pl. XX, fig. 2). The number of the caudal vertebræ in *Dimorphodon macronyx* was at least thirty; the termination of the specimen figured in Pl. XIX, fig. 4, does not indicate a loss there of as many centrums as would bring the number up to thirty-eight, which are assigned by Von Meyer to his *Rhamphorhynchus Gemmingi*.

As we cannot, therefore, with Soemmerring, insist on the shortness of the tail in some *Pterosauria* as proof that they were Birds, so neither can we conclude from the length of the tail in other *Pterosauria* that they were Reptiles. The legitimate taxonomic deduction from such caudal modifications is, that they are not of sufficient importance for determination of a class, and that they do not exclusively characterise the genus. They indicate adaptations in an extreme and variable part or appendage of the body to special powers or ways of movement, or sustentation, in air of the present group of volant animals.

So, likewise, it cannot be, as it has been, inferred from the length of tail in *Archæopteryx*, that it was a Reptile.[2] What we learn from that Avian fossil is akin to what we have learnt from Pterosaurian remains, viz., that the tail is a seat of extreme modification, in respect of length and number of joints, within the limits of the feathered class. Mammalogists, with a like drift, could add instructive evidence of corresponding caudal variability within the limits of the order, as in the volant *Cheiroptera*, and even within the bounds of the family (*Bradypus* and *Megatherium*, *e.g.*).

The value of the discovery of *Archæopteryx*, in relation to *Pterosauria*, is enhanced by the peculiar nature of the matrix, conservative of cutaneous as well as of osseous characters; showing casts of down and feathers,[3] impressions of the fine foldings or wrinkles of thin expansions of naked skin, as well as delicate tendons surrounding, working, strengthening, and stiffening the caudal framework.

With these parts the fine lithographic lime-marl should have preserved the plumose appendages of the long tail of *Rhamphorhynchus*, if that flying Reptile had possessed such; and, along with caudal plumes and vertebræ, should have been preserved the bone-tendons of the tail, if *Archæopteryx* had possessed that structure.

It is probable, from the constancy with which caudal vertebræ of long-tailed

[1] In 'Leonhard und Bronn's Neues Jahrbuch für Mineralogie,' &c., Jahrgang, 1857, p. 536.

[2] *E.g.*, as the *Gryphosaurus* of Andreas Wagner.

[3] A few of the delicate, downy body-feathers of *Archæopteryx* are clearly indicated near one side of the trunk in the slab with most of the bones of the specimen of *Archæopteryx* in the British Museum.

Pterosaurs have been found associated with their tendons,[1] that detached caudal vertebræ of *Archæopteryx* might be recognised through the want of them.

We may confidently conclude that the Oolitic mud which has entombed the greatest number and variety of the flying reptiles of its period would have shown us, when petrified into lithographic slate, their feathers, if, as warm-blooded animals, they had needed such heat-conserving a covering. The plumose clothing of the long-tailed bird of the period proves its hæmatothermal character, as the want of it shows the long-tailed pterosaur to have been cold-blooded.

The tyro, fresh from the lecture-room of his physiological teacher, ambitious of soaring into higher regions of biology than were opened to him at the medical school, impressed with the relations of active locomotion to generation of animal heat, may be pardoned for inferring that the amount of work involved in sustaining a Pterodactyle in the air would make it, physiologically, highly probable that it was a hot-blooded animal. But a competent friend, finding him bent on rushing with such show of knowledge into print, would counsel him to provide himself with a thermometer adapted to the delicate testing of the internal heat of small animals. So provided, if he should chance to beat down a chafer in full flight, the experiment, made with due care and defence of the fingers guiding the instrument, would teach him how fallacious would be the inference that, because an animal can fly, it must, therefore, be hot-blooded. Unless he happen, in introducing the bulb by the widened vent into the abdomen, to plunge it into a mass of ova, he will find the heat of the beetle, notwithstanding the amount of work involved in sustaining and propelling itself in air, not to exceed by more than one degree that of the atmosphere. If he has knocked down a female cockchafer prior to oviposition, the ovarian masses may indicate half a degree, or even one degree, higher of temperature (Fahr.). With the cooling of the air in the summer night the temperature of the *Melolontha* concurrently falls. So, likewise, would that of the flying reptile, whatever "amount of oxidation and evolution of waste products in the form of carbonic acid"[2] might have attended their exercise of flight. The constant correlative structure with hot-bloodedness is a non-conducting covering of the body. We may with certainty infer that *Archæopteryx* was hot-blooded, because it had feathers, not because it could fly.

There is no ground, from observation of the Sharks and Porpoises that accompany swift-sailing vessels, maintaining themselves near the surface, exercising their several and characteristic evolutions in quest or capture of prey, for inferring that the amount or the energy of muscular action is very different in the two surface-swimmers.

Sharks have and, no doubt, work a greater proportion of muscle than Cetaceans; a less proportion of their body is excavated into visceral cavities. Yet the Shark is cold-blooded; its temperature rises and falls with that of its medium; it has no provision, by

[1] As seen in Pl. II, at *cd*, and in Pl. III, figs. 3, 4, 5.

[2] 'Proceedings of the Zoological Society,' April, 1867, p. 417, Prof. Huxley "On the Classification of Birds."

a blanket of blubber or other superficial modification, in aid of the maintenance of a fixed and high degree of blood-heat.

There are conditions, it is true, in which a Reptile generates a higher degree of heat than is usual, but they are not those accompanying any unusual or excessive muscular work and waste; they are attended with rest, not locomotion. The incubating Boa gives to the hand that may be insinuated between the coils surrounding the eggs the sensation of a warm-blooded animal. Valenciennes[1] found, in the Reptile-house at the Jardin des Plantes, when its temperature, in the month of May, was 23° (Centigrade), that the heat of the *Python*, between the folds and upon the eggs, was 41·5° (ib.); so also the heat of the incubating surface of the Bird may rise to 10 degrees (Centigr.) above the ordinary temperature—higher in this passive state than it ever reaches during flight.

The organic condition which determines the hot-blooded or cold-blooded nature of a volant Vertebrate is the separation or the commingling of the arterial and venous bloods in the course of their respective circulations. From the demonstrated absence of any heat-retaining covering of the skin in *Pterosauria*—the kind and amount of negative evidence hereon being decisive—I infer that the black and red sanguineous streams were mixed by intercommunication of the aortic trunks of the right and left ventricles, as in the Crocodile.[2] The plumose integument of *Archæopteryx* bespeaks the separation, not only of the pulmonic and systemic ventricles, but of the arterial trunks thence arising; it was, consequently, hot-blooded, not because it could exert the muscular force required to sustain itself in the air. The all-important condition of the circulating system has wide correlations, not only with the extensive superficies acting upon the surrounding medium, and being reacted upon thereby, but with a rapid and uninterrupted respiration, with an advanced status of the nervous system, especially the brain, involving higher intelligence and more lively and varied instincts, especially the parental. In the organic character determining temperature, breathing, and higher phenomena of life, Birds agree with Mammals and differ from Reptiles.

Birds agree with Implacental Mammals (*Lyencephala*) in the development, by the embryo, of a vascular allantois devoid of villi for placental connection.[3] They agree with the same Mammals and differ from Reptiles in the transversely and deeply folded cerebellum, and in the larger proportion of that and of the cerebrum to the optic lobes. Birds resemble Reptiles in the absence, not only of a corpus callosum, but of a fornix and hippocampal commissure. The *Lyencephala* have the hippocampal commissure, but no

[1] "Faites pendant l'incubation d'une femelle du Python à deux raies (*Python bivittatus*, Kuhl)," &c. 'Comptes rendus de l'Acad. des Sciences,' Paris, 19 Juillet, 1841.

[2] 'Anat. of Vertebrates,' *i*, pp. 510—512, figs. 339, 340.

[3] This character is affirmed to be "of extreme importance, and to define Birds and Reptiles, as a whole, very sharply from Mammals."—Prof. Huxley 'On the Classification of Birds,' loc. cit., p. 416. But, then, the emphatic assertion comes from a writer on Elementary Physiology, who infers the blood of the *Pterosauria* to have been hot because they were able to sustain themselves in air!

corpus callosum; this characterises the Placental Mammalia. Birds differ from other Oviparous Vertebrates in the chalaziferous ovum. The particulars in which Birds differ from all Mammals and agree with Reptiles are comparatively unimportant ones of the skeleton. The occipital condyles (*e.g.*) are more completely blended or unified than in Cetacea. The tympanic is interposed between the mandible and the mastoid, as in Reptiles.[1]

Two genera of Lyencephalous Mammals retain the osteological character common to Birds and Reptiles of the connection of the scapula with the sternum by the intermediation of a fully developed coracoid, and it is one of several and more important characters disproving any sharp definition of the higher warm-blooded Ovipara, at least, from the Ovo-viviparous or Implacental Mammalia.

The scapular arch retains, in *Pterosauria*, its crocodilian simplicity, modified in shape and in the angle at which the scapula meets the coracoid adaptively for the function of flight in the limb suspended thereto. There is, consequently, a close similarity to the same elements in Birds of Flight,[2] but without any trace of the superadded furculum. The articular grooves on the sternum for the coracoids communicate or run into each other at the mid line. The articulation of the corresponding end of the coracoid must be as secure, and yet with as easy a motion, due to a well-turned synovial joint (shown first in *Pterodactylus Woodwardi* and *Pt. simus*),[3] as in any Bird. The confluence of the scapula with the coracoid seems not to be constant in the order *Pterosauria;* and where it has been found, as in *Dimorphodon* and *Pterodactylus Fittoni*, traces of the original suture are present, as represented in the large Neocomian *Pterosauria* in my Monograph of 1859.[4]

In some specimens of *Ramphorhynchus Gemmingi* and in *Ramphorhynchus longicaudus* the scapula and coracoid seemed not to have coalesced.[5] The coalescence is complete and constant (so far as may be inferred from two specimens) in *Dimorphodon.*

For the analysis of the characters of the humerus in *Pterosauria*, I may refer to my Monograph, Suppl. No. III (1861), pp. 13—17, Pl. III. The chief seat of variety is the "radial crest" (Pl. XVIII, 53, *b*, of present Monograph). In the shape and proportions of this extraordinary process *Dimorphodon* resembles *Pterodactylus* more than it does *Ramphorhynchus.* In the proportions of the humerus to the body there is little diversity in the several species.

The antibrachium is commonly two sevenths longer than the humerus. It consists

[1] As a taxonomic character—whatever degree of value may be adjudged to it—this mode of connection of the lower jaw with the skull gains nothing by calling the tympanic 'quadrate bone,' or by affirming it to represent the '*incus*' or the '*malleus*' of Mammalia, whichever may happen to be the favourite fancy of the day.

[2] 'Monograph,' Suppl. No. I (1859), p. 13.

[3] 'Monograph,' Suppl. No. III (1861), p. 12, pl. ii, figs. 7—12.

[4] Suppl. No. I, Pl. III, figs. 1—5.

[5] Von Meyer, op. cit., p. 18.

of two equal-sized, closely and extensively united bones, with one or two slender styliform ossicles attached lengthwise, having the base a little below the distal ends of the radius and ulna. The latter bone shows no pits for the attachment of quill-feathers, as in the hot-blooded volant *Ovipara*. A carpus with one large and one small bone in a proximal row, and with a second large and at least one smaller bone in a distal row, is another character by which the *Pterosauria* manifest their closer affinity to Reptiles than to Birds. The remains of the gigantic species from the Cambridge Greensands have yielded the characters of the two larger carpal ossicles.[1]

Variation, as usual, begins to assert its sway as the segments of the limb recede from the trunk. This is mainly shown in the relative length of the metacarpus. In *Rhamphorhynchus Gemmingi* it is to the antibrachium as 2 to 7, and to the first phalanx of the wing-finger as 1 to 5, or rather less. In *Dimorphodon* the metacarpus is to the antibrachium rather more than 2 to 6, and is little less than one half the length of the first phalanx of the wing-finger. In *Pterodactylus longirostris* the metacarpus is two thirds the length of the first phalanx. In *Pterodactylus longicollum* the metacarpus is almost four fifths the length of the first phalanx of the wing-finger. In *Pt. suevicus* the metacarpus is one eighth longer than the antibrachium.

There are diversities also in the relative length of the phalanges of the wing-finger. In *Dimorphodon* they increase in length from the first to the third. In *Ramphorynchus Gemmingi* the first and second phalanges are of equal length, and the third is shorter. In *Pterodactylus longirostris, Pt. scolopaciceps, Pt. Kochii*, they decrease in length from the first to the third, and in a greater degree in *Pt. suevicus*.

The most marked variety, however, if the structure has been rightly determined or be not due to some accidental mutilation of the individual, is that on which Von Meyer[2] has founded his genus *Ornithopterus*, viz. a reduction in the number of phalanges of the wing-finger from four to two, and the articulation of the proximal one to two large metacarpals. The last pointed phalanx of the wing-finger in *Ramphorhynchus* is rather longer than the penultimate one; in *Ornithopterus Lavateri* it is only one third the length of the penultimate phalanx.

The evidences of pelvic structure in other *Pterosauria*, already referred to, leaves no doubt as to that in *Dimorphodon*, as restored at *s*, 62, 63, 64, in Pl. XX. The expansion of the ischial and pubic elements and the direction of the latter are strong evidences of Reptilian affinity, and decisive differences in the comparison with Birds. Given the greatest number of vertebræ grasped by the ilia, it falls short of the least number presented in the class of Birds, as by certain *Natatores*, which concomitantly manifest a vacillating or waddling gait. Nothing in the structure, proportions, and connections of the pelvic arch squares with the notion of bipedal progression or erect sustentation of the body and wings of the *Pterosaur*. The share taken by the hind limbs

[1] 'Monograph,' Suppl. No. III (1861), p. 17, Pl. II, fig. 6; Pl. IV, figs. 5—9.

[2] Op. cit., p. 25, pl. vi, fig. 5.

in resting or moving on dry ground was that indicated in the restoration of the skeleton in Pl. IV.

The hind limbs of *Dimorphodon* are, nevertheless, larger and stronger in proportion than in other *Pterosauria*. The femur, in most species, equals the humerus in length, and, in *Dimorphodon*, also in thickness. In *Pterodactylus longirostris* and *Pt. Kochii* the femur is the more slender bone; in *Ramphorhynchus* it is likewise shorter than the humerus.

The tibia, more slender than the antibrachial bones, in *Pterodactylus longirostris* and *Pt. Kochii*, is of equal length therewith. In *Dimorphodon* the tibia is less slender in proportion to the antibrachium, and is longer by one seventh. In *Ramphorhynchus* it is much more slender than the antibrachium, and is nearly one third shorter. The ankle-joint works between the tibia and tarsus, which, as in other Reptiles and Mammals, is distinct from the metatarsus. There is no calcaneal prominence, and the foot admits of easy rotation, as in the 'Restoration,' Pl. XX, fig. 2, where the inner toe is turned outward and the sole presented to view, to show the application of the wing-toe in flight to the interfemoral web.

Whether the trochlear terminal joint of the tibia be ossified from a separate centre in the Pterodactyle as in the Bird requires a specimen of the requisite immaturity for determining. If the hind limbs and pelvis presented the structure for sustaining and moving the animal erect on land, an epiphysial state of the articular ends of the long bones might be physiologically inferred. I conclude, from the absence of the modifications essential to bipedal station and progression in *Pterosauria*, that the articular ends of both femur and tibia, including the distal condyles of the latter bone, were co-ossified with the shaft as in other Saurians.

When in warm-blooded Vertebrates, whether Birds or Mammals, the metapodial elements of different toes coalesce, the epiphyses of such coalesced series, or 'cannon bone,' are usually connate, forming a single bone. As, *e.g.*, at the proximal end of the Cow's and Bird's metatarsus (figs. 3 and 4, *c*),[1] and also even at the distal end of the cannon-bone in Ruminants (fig. 3, *d*). I demonstrated the fact in both the metacarpus and metatarsus of a young Giraffe, in my 'Hunterian Lectures' of 1851. The specimens are Nos. 3631 and 3635 in the Osteological Collection of the Royal College of Surgeons ('Catal.' 4to, 1853, p. 601).

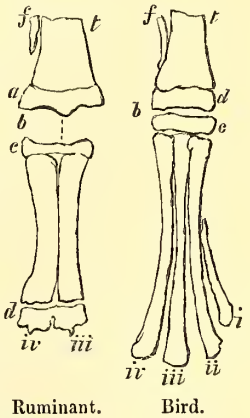


Fig. 3. Fig. 4.
Ruminant. Bird.

The distal trochlear end of the Bird's tibia, in its epiphysial state (fig, 4, *d*), answers to the distal trochlear epiphysis of the Ruminant's tibia (fig. 3, *a*). In its anchylosed state the distal bicondylar trochlear joint or end of the Bird's tibia answers to the distal bicondylar trochlear joint or end of the Pterosaur's tibia. The proximal

[1] "The upper articular surface is formed by a single broad piece. The original separation of the metatarsal bone below into three pieces is plainly indicated."—"On the Anatomy of the Southern Apteryx," 'Trans. Zool. Soc.,' ii (1838), p. 293.

epiphysis of the Bird's metatarsus (fig. 4, *c*) answers to the proximal epiphysis of the Ruminant's metatarsus (fig. 3, *c*).

The interspace between the leg and foot is the seat of variable and inconstant centres of ossification, from zero, as in *Proteus*, *Amphiuma*, *Aves*, to the four ossicles in *Crocodilus*, and the seven ossicles in *Chelone*.

The functions of the hind leg in Birds require peculiarly strong, firm, close-fitting, interlocking joints. Thus, the fibula articulates directly with the femur, and the metatarsus as directly with the tibia. No interposed ossicles are permitted to affect the simple efficiency of this tibio-metatarsal joint in the long-footed feathered bipeds. In quadrupeds and in the short- and broad-footed *Bimana* tarsal ossicles, interposed at the space *b* (fig. 3), have their use. But whether the tarsus exist or not, in the *Hæmatotherma* the articular ends of the long bones begin as 'epiphyses;' and when two or more metacarpals are to become massed into one bone, the epiphysis (*c*) is single—a very significant developmental guide to the homology in question.

The strangest aberrations in homological aims have arisen from a non-recognition of the distinction between teleological and homological centres of ossification.[1] Not only is a tibial epiphysis made into a tarsal bone—and why other epiphyses, such as the proximal one of the tibia, or the distal one of the femur, should be differently treated is not obvious—but new bones by the score are added to the cranial series. 'Basitemporals,' 'prevomers,' 'antorbitals,' 'perpendicular ethmoids,' 'ali-cthmoids,' &c. &c., have been heaped up to obstruct the comprehension of the plain and intelligible nature of the bird's skull.

The four unguiculate digits of the foot are of nearly equal length, but present a slight difference in their proportions[2] in the *Pterosauria*. Cuvier having determined the Lacertian character of the phalangial formula of these digits, viz. 2, 3, 4, 5, adds that, apparently, the fifth digit was reduced to a slight vestige of two pieces in *Pterodactylus longirostris*.[3] Subsequently discovered species have offered a like indication, to which Von Meyer alludes as a rudiment or stump ('stummel') of the fifth toe.[4] No other specimens, to my knowledge, save the third of *Dimorphodon* (Pl. XVIII) and the *Ramphorhynchus* (Pl. XIX, fig. 5) have shown the condition of the fifth digit as of three pieces, viz. a metatarsal (*m*, *v*) and two phalanges (*v*, 1 and 2).

The metatarsal of this toe shows an interesting affinity to that in the *Crocodilia* by its greater breadth and shortness in comparison to the other metatarsals. The two phalanges have proportions and forms which clearly show their adaptive relations as aids in sustaining the interfemoral or caudo-femoral parachute ('Restoration,' fig. 2, Pl. XX).

[1] Owen, "Lectures on the Comp. Anat. of Vertebrate Animals," 8vo, 1846, p. 38.

[2] See Monograph, pl. xi, fig. 3.

[3] "Il paroit qu'ici le cinquième étoit réduit à un leger vestige de deux pièces."—'Oss. Foss.,' vol. cit., p. 374.

[4] "Cuvier, Wagler, und Goldfuss lassen den Fuss aus fünf ausgebilteten Zehen bestehen; in allen Pterodactyln habe ich aber nie mehr als vier solcher Zehen, und höchstens noch einen Stummel vorgefunden."—Op. cit., p. 20.

The crushed condition of most of the long bones in the specimens of *Dimorphodon* show the wall of the shaft to have been compact and thin, the cavity large. Although I have failed to detect such clear evidence of the foramen pneumaticum in these crushed bones as in some of the vertebræ, I cannot resist the inference from the structure of the long bones that they were filled with air in the living animal, as has been demonstrated in remains of the larger *Pterosauria* of the Cretaceous series.[1]

This general osteological character of the *Pterosauria* leads me to offer a few remarks on its relation to their peculiar power of locomotion among *Reptilia*, and to the affinity it may indicate to other groups of volant Vertebrates.

Weight is, of course, indispensable to directed motion through the air; but, given the weight requisite for the action against gravity resulting in flight, whatever structure tends to dispense with additional burthen enables the force to act with more avail—with less unnecessary resistance to overcome.

Where provision is made for unusual flying force, as by the enormous pectoral muscles and concomitant shape of wing in the Swift, the required weight of body called for heavier bones; hence the non-pneumaticity of the skeleton. Diminished flying force, especially with increased bulk of body, is attended with modifications of bony structure obviously adapted, and which have always been recognised in relation, to reduction of weight in the mass to be moved through the air. It is true that the mere quantity of air contained in bones would have an effect inappreciable in aid of the force raising a weight of 5 lb. or 10 lb. from the ground;[2] but the true view of the question is—given a bone of 1 foot in length and 3 inches in circumference, whether the restriction of bony matter to a thinness of $\frac{1}{2}$ a line at the circumference, and a substitution of air for the rest of the diameter throughout the shaft, be not a provision for diminution of weight and conservation of strength which does relate to facilitate locomotion through air?

If the humerus of the Ostrich (No. 1373, Osteological Collection in the Museum of the College of Surgeons, London, 'Catalogue' of do., 4to, 1853, p. 265) be compared, as to weight, with the similarly sized humerus of the Argala Crane (No. 1107, ib., 'Catal.,' p. 214), the difference is striking and suggestive; the latter bone being "remarkable for its lightness, as compared with its bulk and seeming solidity" (ib., 'Catal.' ib.). I demonstrated the cause of the difference by a longitudinal section of

[1] 'Monograph on the Fossil Reptilia of the Cretaceous Formations (Order *Pterosauria*),' ('Pal. Soc. Mon.', vol. v), 4to, 1851, pp. 80, 98, 101.

[2] A writer impugning the physiological inferences of Hunter and Camper, the discoverers of the pneumaticity of the bird's skeleton, remarks:—"A living bird weighing 10 lb. weighs the same when dead, plus a very few grains; and all know what effect a few grains of heated air would have in raising a weight of 10 lbs. from the ground. The quantity of air imprisoned is, to begin with, so infinitesimally small, and the difference in weight which it experiences by increase of temperature so inappreciable, that it ought not to be taken into account by any one endeavouring to solve the difficult and important problem of flight."—Pettigrew, "On the Mechanism of Flight," 'Linnean Transactions,' vol. xxvi, p. 218, 1868.

the two bones. In the Bird incapable of flight the humerus is solid; in the Bird remarkable for the long-continued power of soaring in upper regions of the air the shaft of the bone is a 'thin shell of compact osseous tissue.' The relation of the weight of the volume of air occupying the capacious cavity of the Argala's wing-bone to the total weight of its body need not be taken into account in considering the problem of flight, but the relation of a hollow instead of a solid humerus is a legitimate element in the endeavour to solve that complex kind of animal locomotion. To say that a certain amount of weight in the bird is essential to the momentum of flight is no argument against the reduction to such requisite weight of the body to be upborne. Every structure so tending to lighten the body of a volant animal within the required limit is, and ought to be, recognisable as physiologically related to flight.

By the pneumaticity of the bones of the Pterodactyle, it might be inferred, from a single bone or portion of bone, to have been an animal of flight. For, although certain volant Vertebrates, *e.g.* the Bat and the Swift, may not have air-bones, no Vertebrate save a volant kind has air admitted into the limb-bones. But the effect of such admission, of such substitution of a lighter for a heavier material, is to diminish the weight without impairing the strength of the bone; the legitimate, if not sole, inference, therefore, is that it contributes to perfect the mechanism of flight.

It is a purely adaptive character, and the insignificant, barely appreciable, difference of weight due to difference of temperature in a given bulk of air makes the pneumaticity of the skeleton as available and advantageous to a cold-blooded as to a warm-blooded volant Vertebrate.

In concluding the description of the subjects of the present Monograph I am moved again to express my sense of acknowledgment for the most instructive of the evidences of *Dimorphodon macronyx* due to my friend from the beginning of our palæontological pursuits, the Earl of Enniskillen, F.R.S.; and, whilst fulfilling this pleasurable duty, I would add a testimony to one whose loss Palæontology has much reason to deplore,—to the unwearied and undaunted explorations of the precipitous cliffs of Lyme-Regis by Mary Anning, to which, and to her singular tact of discernment of the feeblest evidence of a fossil in that dark matrix, science is indebted for the discovery of the first evidence of a Pterosaur in 'Lias' of the locality, which has since yielded the grounds for the reconstruction of the strangest representative of the order.

Ramphorhynchus Meyeri, Pl. XIX, fig. 5.—In further illustration of the characters of *Dimorphodon macronyx* I have added to Pl. XIX a figure of a long-tailed Pterosaur from the lithographic slate of Pappenheim, which, in the feebleness of its hind-limbs and the general proportions of the tail, resembles *Ramphorhynchus Gemmingi*, V. M.[1]

[1] See Von Meyer, op. cit., pl. ix, fig. 1.

The present specimen, from Dr. Häberlein's collection, now in the British Museum, shows the fifth or 'wing-toe' of the foot, ib. fig. 5, *v*, which had not been preserved in previously described specimens of the genus.[1] At least thirty-four vertebræ extend beyond the sacrum; thirty-eight caudals are the reckoned by Von Meyer in the specimen of his *R. Gemmingi* with the best preserved tail;[2] but this difference would not have yielded sufficient ground for specific distinction. There are, however, differences in the length of the parts of the hind limb which indicate this to have been longer in proportion to the tail and the 'symphysis mandibulæ' than in *R. Gemmingi*.

	R. Meyeri.		*R. Gemmingi* (pl. ix, V. M., op cit.).	
	in.	l.	in.	l.
Length of femur	1	$2\frac{1}{2}$	1	0
„ tibia	2	0	1	8
„ 1st toe	1	6	1	$2\frac{1}{2}$
„ 2nd toe	1	9	1	4
„ 3rd toe	1	$11\frac{1}{2}$	1	6
„ 4th toe	1	$10\frac{1}{2}$	1	3
„ 5th toe	0	9		

In both specimens the number of phalanges of the toes increases from the first or innermost to the fourth, in the usual saurian ratio, 2, 3, 4, 5. In *Ramphorhynchus Meyeri* the fifth toe consists, as in *Dimorphodon*, of two phalanges, the first being six lines in length, the second three lines, and ending in a point. The metatarsal of this 'wing-toe' is short, broad, and flattened, with a convex outer border at its basal half.

The bones of the left hind limb are well preserved in the specimen figured.

The caudal vertebræ are surrounded by the bone-tendons. Their proportions, as shown in the figure, accord with those in *Dimorphodon*, Pl. XIX, fig. 4.[3] The posterior dorsal vertebræ of *Ramphorhynchus Meyeri* show the broad diapophyses supporting the ribs, which are more slender than those at the fore part of the chest. The symphysis mandibulæ is one inch six lines in length, including the edentulous pointed end. Four pairs of long slender laniary teeth are preserved at the fore half of the symphysis. The teeth at that part of the lower jaw in *Ramphorhynchus Gemmingi* are fewer in number and less closely arranged.[4]

[1] "Ein Stummel wur nicht mit Sicherheit zu ermitteln."—Von Meyer, op. cit., p. 72.

[2] Op. cit., p. 69.

[3] This figure has the neural surface downward in the Plate.

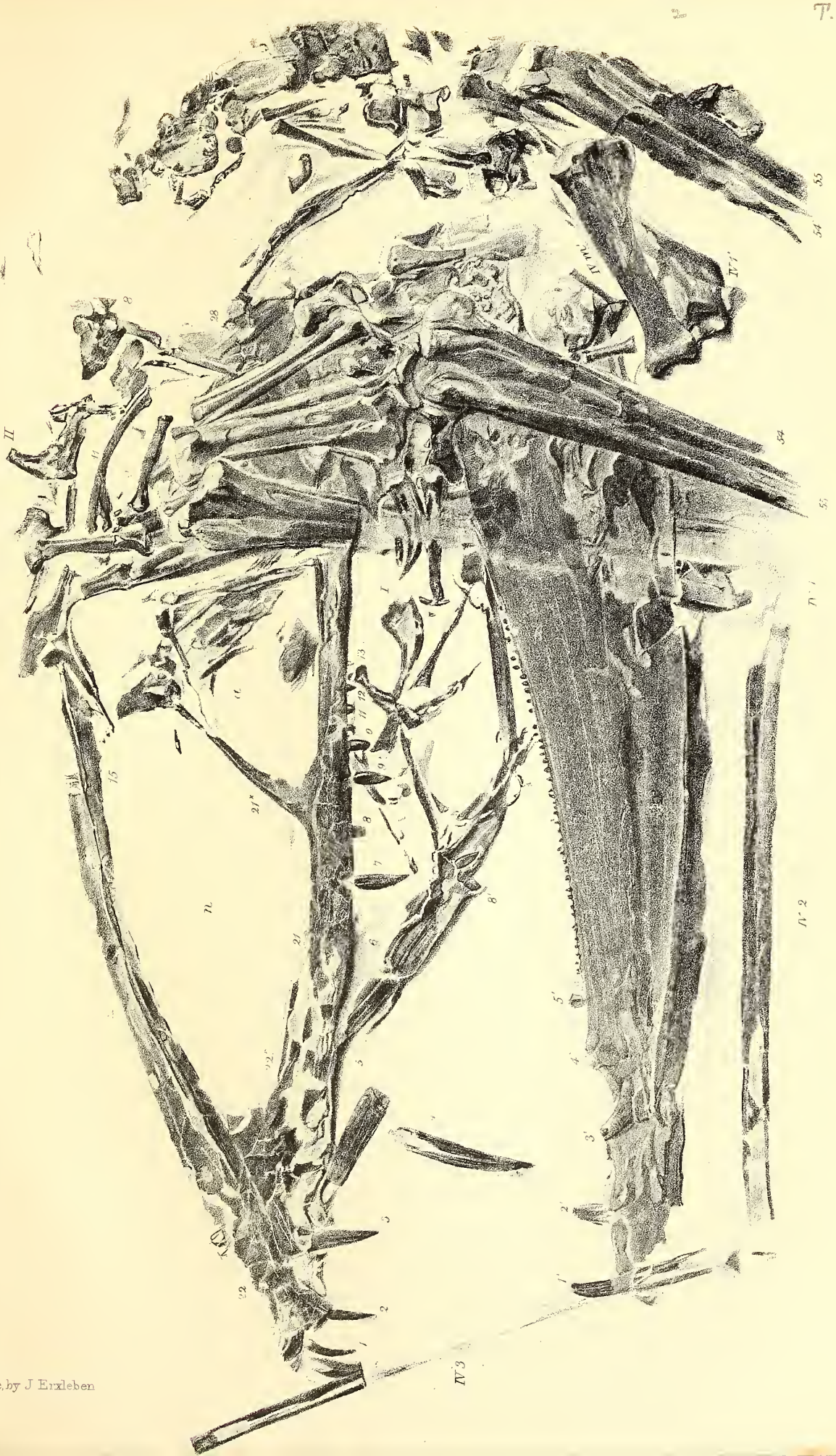
[4] Compare with Von Meyer, op. cit., pl. ix, fig. 1, and pl. x, fig. 1.

PLATE XVII.

Dimorphodon macronyx.

Skull and parts of the skeleton : nat. size.

From the Lower Lias of Lyme Regis. In the British Museum.



DIMORPHODON MACRONYX

at on Stone, by J Erxleben

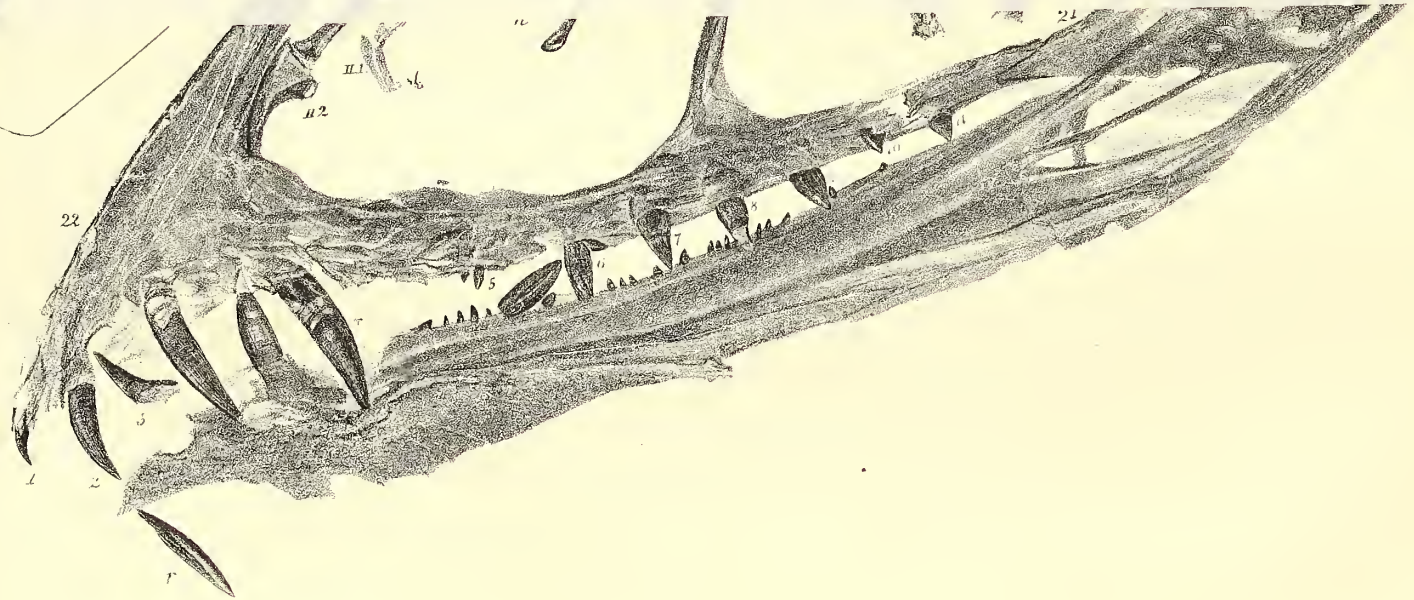
W. West imp

PLATE XVIII.

Dimorphodon macronyx.

Skull and parts of the skeleton: nat. size.

From the Lower Lias of Lyme Regis. In the British Museum.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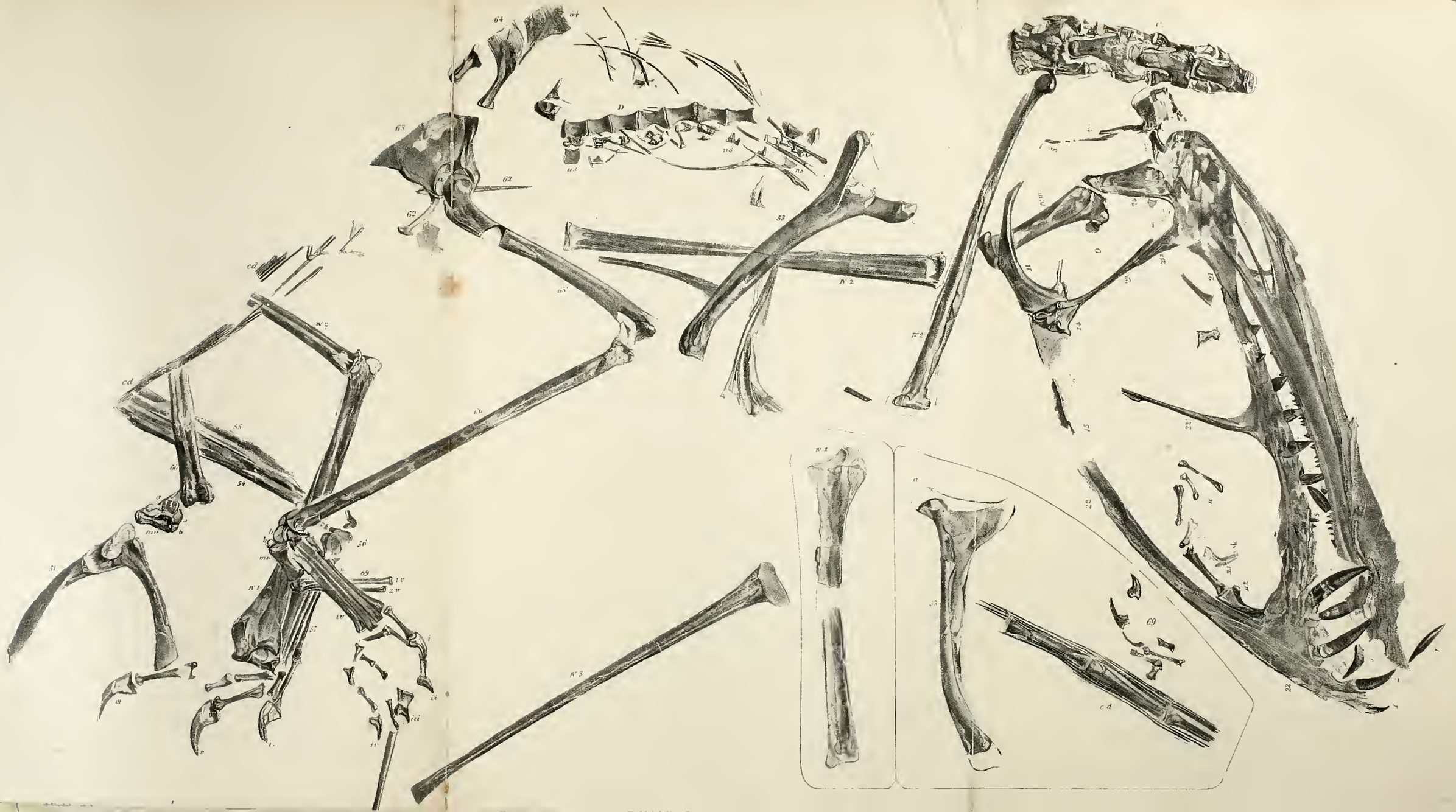
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PLATE XIX.

Dimorphodon macronyx.

Fig.

1. Bones of fore foot and part of wing-finger.
2. Pelvis.
3. Anterior caudal vertebræ.
4. Vertebræ of entire tail, with surrounding bone-tendons.

From the Lower Lias of Lyme Regis, Dorsetshire.

Rhamphorhynchus Meyeri.

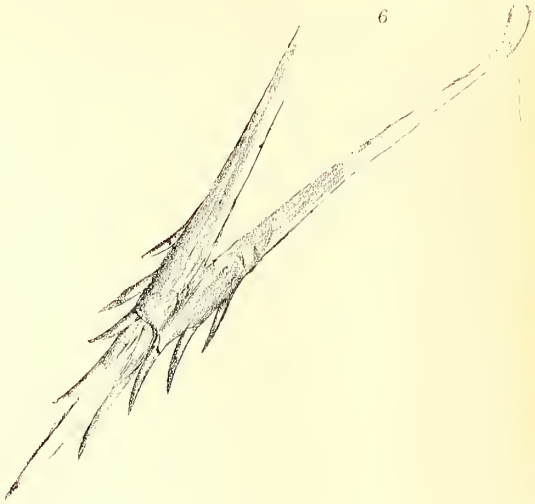
5. Dorso-lumbar, sacral, and caudal vertebræ, part of pelvis, with bones of the pelvic limbs.
6. Fore part of mandible and teeth.

From the Lithographic Slate, Pappenheim, Bavaria.

7. Second phalanx of wing-finger of *Pterodactylus validus*.
8. Distal end, and section of shaft, of tibia of *Pterodactylus curtus*.
9. Ib. ib., side view, of do. do.
10. Section of second phalanx of wing-finger of *Pterodactylus nobilis*.

From the Wealden of Sussex.

All the specimens of the natural size. In the British Museum.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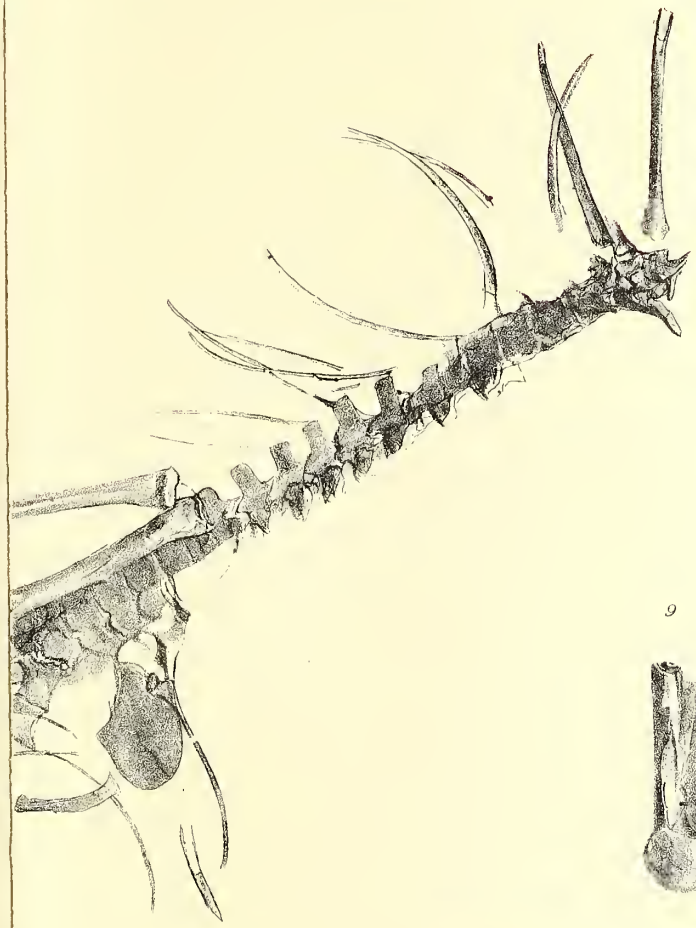

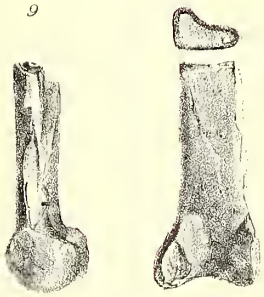
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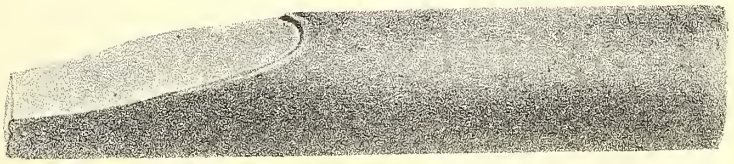

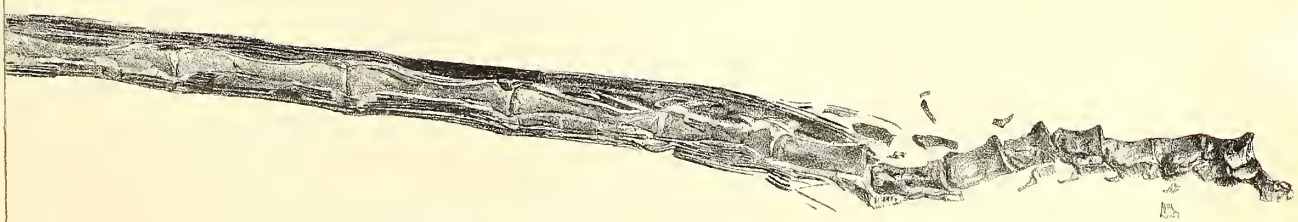

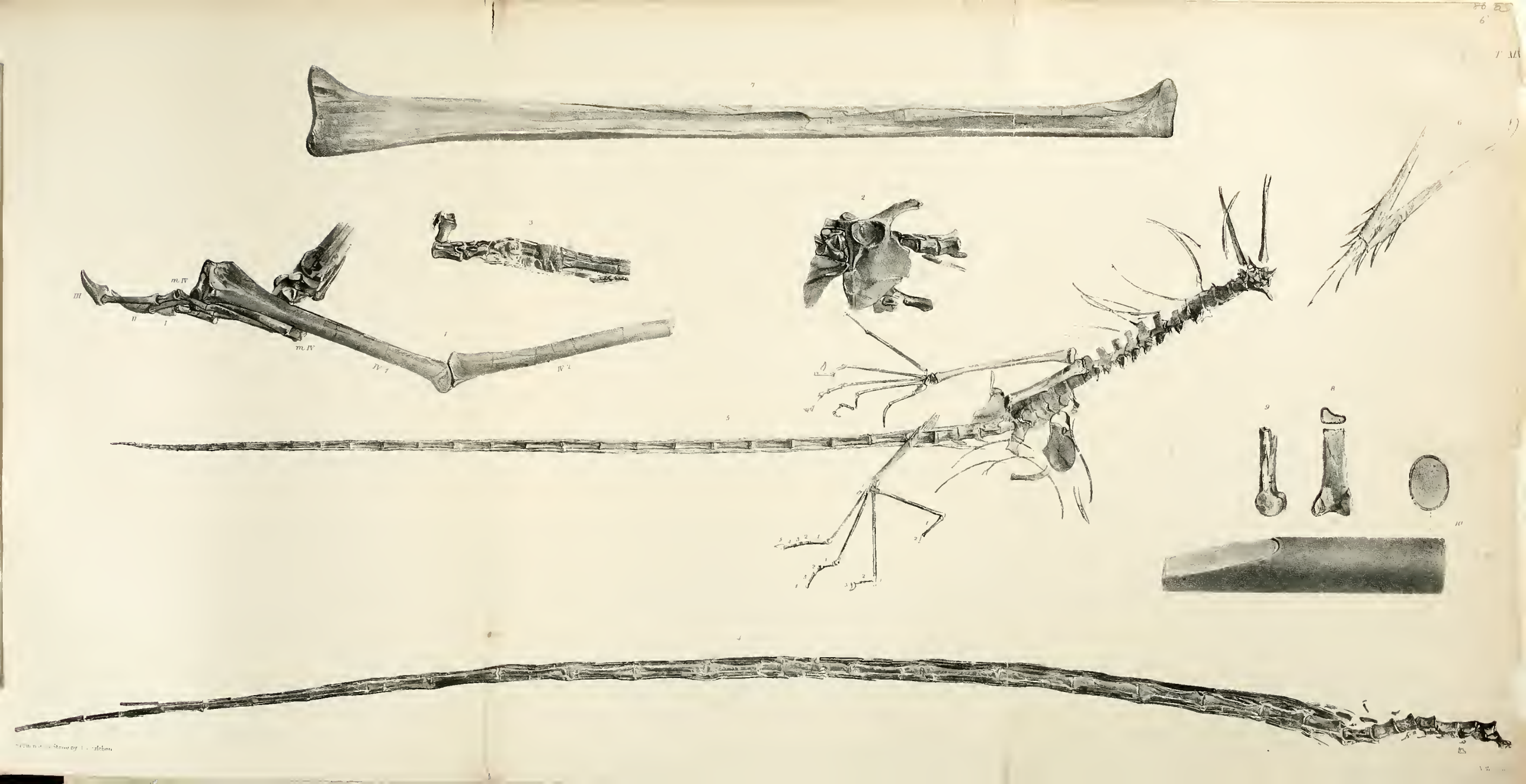
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PLATE XX.

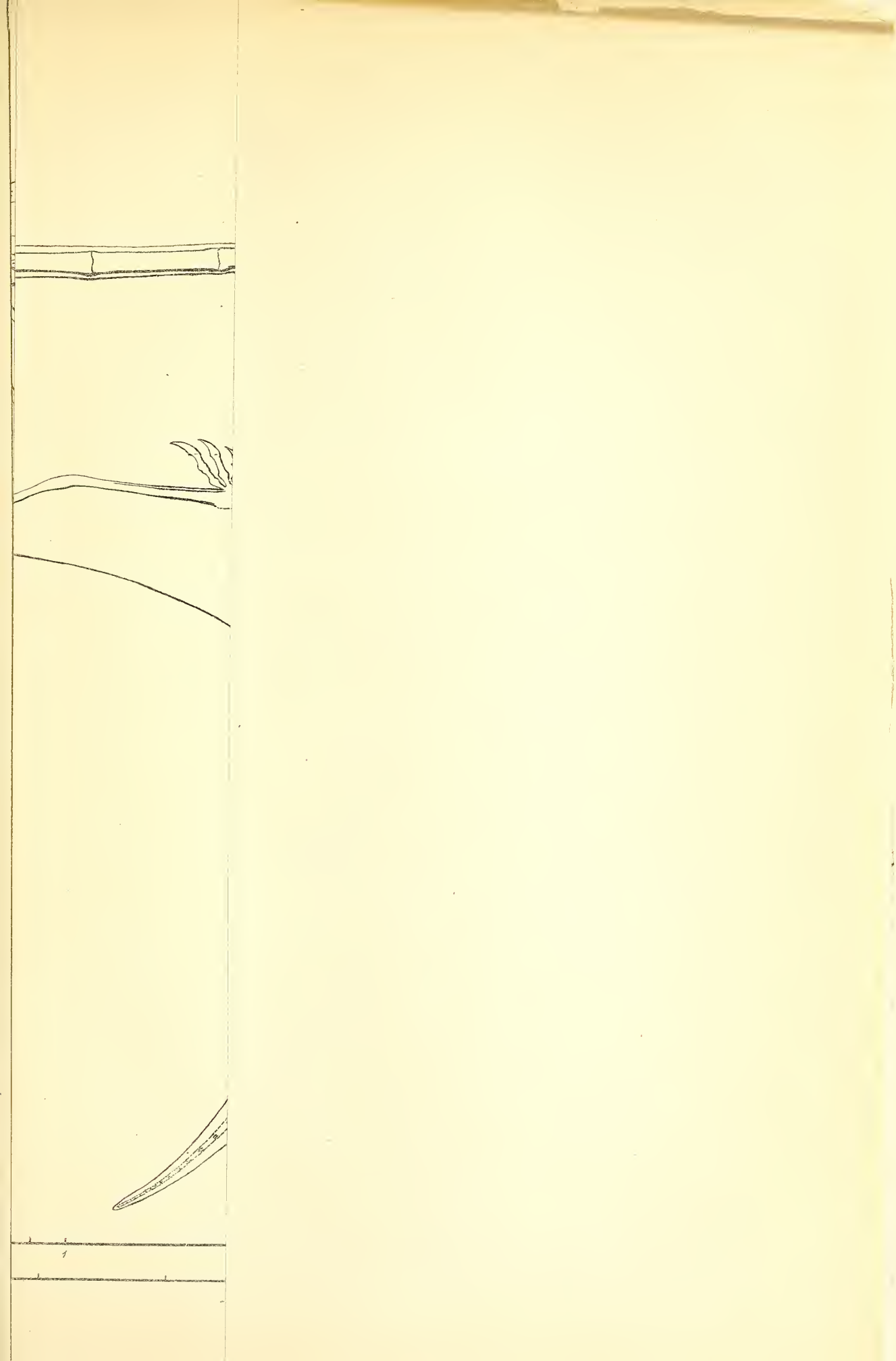
Dimorphodon macronyx.

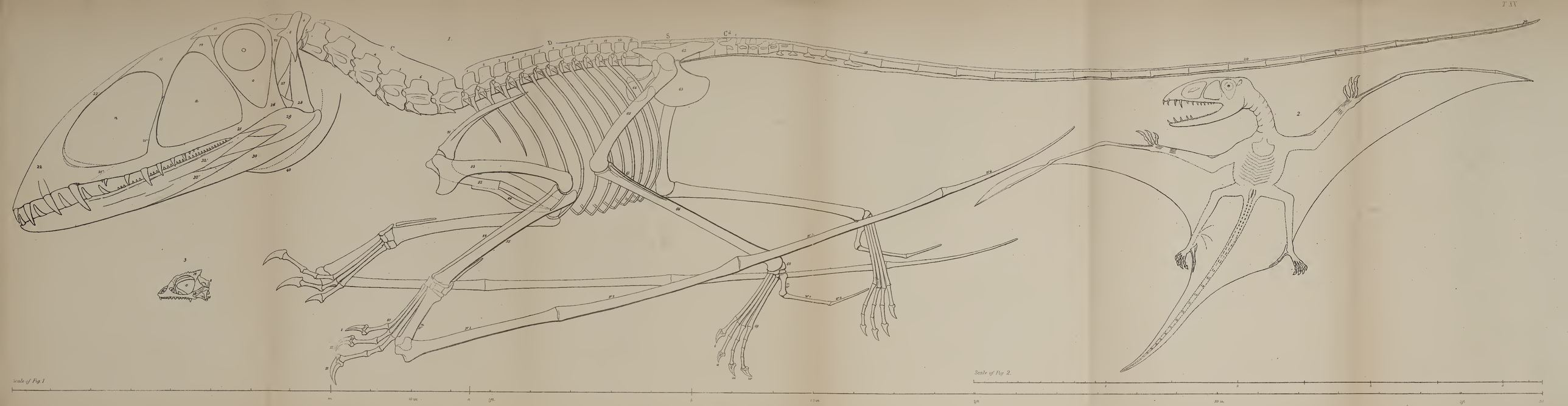
Fig.

1. Restoration of the skeleton : nat. size.

2. Restoration of entire animal : reduced (see ' Scales' at foot of plate).

3. Side view of the skull of a recent Saurian (*Lyriocephalus*).





R. Owen del. On Stone by T. Worthington

RESTORATION OF DIMORPHODON.

W. West

A MONOGRAPH

OF

THE FOSSIL REPTILIA

OF THE

LIASSIC FORMATIONS.

BY

PROFESSOR OWEN, C.B., F.R.S.,

FOREIGN ASSOCIATE OF THE INSTITUTE OF FRANCE,

ETC. ETC.

PART THIRD.

ICHTHYOPTERYGIA.

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THE FOSSIL REPTILIA OF THE LIASSIC FORMATIONS.

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The Title-page in the volume for the year 1881 is inscribed "Reptilia of the Liassic Formations. Part Third, Ichthyopterygia."

MONOGRAPH

ON

THE FOSSIL REPTILIA

OF THE

LIASSIC FORMATIONS.

Class—*REPTILIA*, Cuv.[1]

Order—Ichthyopterygia, *Owen*.[2]

Genus—Ichthyosaurus, *König*.[3]

A. Introduction.

Remains of the extinct marine Reptiles, now known as *Ichthyosaurs*, have attracted the attention of collectors and describers of organic fossils for nearly two centuries past.

In Scheuchzer's 'Querelæ Piscium,' 1708, tab. iii contains figures of the biconcave vertebræ of an *Ichthyosaur* from the Lias of Altdorf, supposed to be a fish. Knorr, also, in his 'Naturgeschichte der Versteinerungen,' vol. ii, represents, in figs. 5—7 of tab. i, vertebræ of the same Reptile, as "*Ichthyospondylen*."

So, likewise, when the attention of more modern palæontologists was awakened to remains of the remarkable subjects of the present Monograph, as in the paper by Sir Everard Home, Bart., F.R.S. ('Philos. Trans.,' 1814), we find such described as "Fossil Remains of an animal more nearly allied to Fishes than any of the other classes of animals."

In this paper, however, as in succeeding ones by the same author, which appeared in the 'Philosophical Transactions' for the years 1816, 1818, 1819, and 1820, the accurate and beautiful engravings of the drawings of the several subjects by

[1] Reptiles, *Cuv.*, 'Tableau Elémentaire de l'Histoire Naturelle des Animaux,' 8vo, An. vi (1797), p. 281.

[2] "On the Orders of Fossil and Recent Reptilia," 'Report of the British Association for the Advancement of Science,' 1859, 8vo, pp. 155, 159.

[3] 'Icones Fossilium Sectiles,' fol., pl. xix, fig. 250.

William Clift, F.R.S., enabled contemporary investigators, more capable than Home in determining the true nature and affinities of the fossils, to contribute a durable and rich accession to their science.

In this work the names of Conybeare and De la Beche[1] stand pre-eminent, and with them must be associated that of Charles König, whose appreciation of the affinities of the animal, the fossil remains of which he figured in the work above cited, is exemplified by the generic name which the extinct Reptile has subsequently borne.[2]

Baron Cuvier amply confirmed the conclusions to which the above-cited authors, and, subsequently, Conybeare[3] arrived, and introduced copies of figures illustrative of their papers in the concluding volume of his great work on 'Fossil Remains.'[4]

In the same year Prof. George Fred. Jaeger recognised fossils as Ichthyosaurian in the Lias of Boll, to one of the plates in whose Work reference will be subsequently made.[5]

Subsequent additions to the history of the genus *Ichthyosaurus* will be found in my 'Report on British Fossil Reptiles,' in the volume of the British Association for the year 1839, 8vo., p. 86.

Before entering upon the details of structure and specific characters I may remark that whenever the antecedent representatives of a class or order may be known, to which an extinct genus is referable, the characters of the genus should be compared with those of its predecessors in such class, rather than with its successors or with existing forms, to gain an insight into its true affinities.[6]

The Labyrinthodont order, prevalent from the Carboniferous to the Triassic formation, manifests the tendeney to dermal or peripheral ossifications which was carried out to greater extent in older and lower vertebrate forms. The Ichthyopterygian order, prevalent from the Liassic to the Cretaceous period, continues to show the supplementary 'prosquamosals' (Pls. XXIII and XXIV, fig. 1, 27′) and 'postorbitals' (ib. ib., 12); and the vertebral centrums retain the biconcave character (Pl. XXII, fig. 6). The 'foramen parietale' (Pl. XXIII, fig. 1, *f*) is common in Carboniferous,[7] Permian, and Triassic

[1] "Notice of a Discovery of a new Fossil Animal forming a link between the *Ichthyosaurus* and Crocodile; together with general remarks on the Osteology of the Ichthyosaurus," 'Transactions of the Geological Society,' 4to, vol. v, 1821, p. 559, pls. lx, lxi, lxii.

[2] "We have retained in these observations the name Ichthyosaurus, originally applied to this animal by Mr. König, of the British Museum, feeling convinced that on a full and careful review of its whole structure it will not be found to possess analogies sufficiently numerous or strong with the peculiar organisation of Proteus to authorise the change of this appellation into Proteosaurus, as subsequently proposed." —Tom. cit., p. 563, Conybeare and De la Beche.

[3] "Additional Notices on the Fossil Genera Ichthyosaurus and Plesiosaurus," 'Trans. of the Geological Society,' 2nd series, vol. i (1824), p. 103.

[4] 'Recherches sur les Ossemens Fossiles,' 4to, tome 5ème, 2de partie, 1824, p. 447, pl. ii.

[5] 'De Ichthyosauri sive Proteosauri fossilibus speciminibus in Agro Bollensi repertis,' 4to, 1824.

[6] Owen, 'Palæontology,' 8vo, 1860, p. 206.

[7] "Ueber *Archegosaurus Decheníi*, Goldf.," von Dr. G. Jäger, 4to, 'München Abhandl.,' Bd. v, 1847, p. 415, tab. xxvi, fig. 1.

Reptiles; and, in some, is larger than in *Ichthyosaurus*,[1] whence it has been continued on to modern *Lacertilia*, but has become obliterated in the Crocodilian order. Both diapophyses and parapophyses[2] appear in Reptilian vertebræ at the same geological period, and are carried on in the Crocodilian modification of the class, but are lost in existing *Lacertilia*. They are conspicuous Ichthyopterygian characters, and are associated, as far along the spine as they are distinctly developed, with the double-jointed ribs, showing 'capitulum' and 'tuberculum' (Pl. XXI, fig. 2, *a*, *b*). The prezygapophyses of the atlas converge, descend, and aid in forming the anterior cup, which receives a corresponding convex joint-surface of the occipital vertebra; the change from the double condyle of the oldest air-breathing Vertebrates to the single condyle in Triassic Reptilia is retained in the *Ichthyopterygia*. The teeth in this order show a trace of the older Labyrinthodont character in the converging folds of cement penetrating their base,[3] but the alveolar partitions of their native groove are not complete in any part of the tooth-bearing tract. Anchylosis of the tooth-root to the jaw, seen in Mosasauroids and modern Lizards, is not effected in any Ichthyosaur. The teeth retain this freedom, as in Crocodiles, with a similar repeated succession and shedding; as in Crocodiles, also, they are confined to the maxillary, premaxillary, and premandibular ("dentary") bones, but with the ordinal character of much greater length of the premaxillaries than of the maxillaries. The orbits, in *Ichthyopterygia*, are conspicuous for their size; the circle of sclerotic plates usually found fossilised in them exemplifies a primitive vertebral character under a modification continued on in *Chelonia*, *Lacertilia*, and *Aves*. The nostrils are distinct, and antorbital in position. The limbs are natatory, with many-jointed digits, and these exceed, in some Ichthyosaurian species (Pl. XXX, fig. 3), five in number. The scapular arch (Pl. XXVIII, fig. 4, *Ich. latimanus*, *Ich. communis*, e. g.), includes an episternum (46) and clavicles (58), with a well-developed coracoid (52) and scapula (51), the latter near to, but detached from, the occiput. The hinder part of the vertebral column is as free for natatory work as in Whales; there is no sacrum, but a pair of pelvic fins is constant, and these, usually smaller than the pectoral ones, are supported by iliac, ischial, and pubic bones. The terminal caudals are modified for the support of a tegumentary fin, but are compressed, not depressed, the fin being vertical, not horizontal.

The adaptive modifications of the Ichthyopterygian skeleton, like those of the Cetacean, relate to their medium of existence; they are superinduced, in the one

[1] 'Descriptive and Illustrated Catalogue of the Fossil Reptilia of South Africa in the British Museum,' 4to, 1876; *Galesaurus*, pl. xviii, fig. 8, 7′; *Petrophryne*, pl. xx, fig. 18, 7′; *Gorgonops*, pl, xxi, fig. 3, 7′; *Dicynodon*, *Ptychognathus*, *Oudenodon*, *Kisticephalus*, pls. lxiv, lxv; *Procolophon*, pl. xxii, figs. 4, 8.

[2] Op. cit., *Pareiasaurus*, pl. x, figs. 1, 3, *d*, *p*; *Dicynodon*, pl. lii, fig. 1; pl. liii, fig. 3, *d*.

[3] A transverse section of the base of the tooth of an Ichthyosaur gave the first clue to the structure of that of the *Labyrinthodon*. 'Odontography,' 1840, p. 201, pl. lxiv B, fig. 3.

case upon a Reptilian, in the other upon a Mammalian type, and both show analogies to the Vertebrates which the "waters first brought forth." But that the Ichthyopterygians did not breathe by means of gills is shown by the absence of the branchial framework, and by the presence, position, and structure of passages leading from the nostrils to the palate for the course of currents of air on their way to lungs, which were protected and worked by movable thoracic-abdominal costal girdles. Herein these old Sea-reptiles rise higher in structure than some modern cold-blooded air-breathers such, *e.g.* as Batrachians and Chelonians.

An Ichthyosaur by the shortness, one may say absence, of neck, and equality of width of the back of the head with the front of the chest, shares with the Whale a resemblance to Fishes, but pushes the likeness closer in the greater number and less length of the vertebræ, and in the indication of the main joints of the backbone being elastic bags filled with fluid, occupying the intervertebral spaces of the biconcave centrums, as in Fishes, Labyrinthodonts, and modern perennibranchiate Batrachians.

Being cold-blooded, and with a small brain needing a much less supply of oxygen for its work, the Ichthyopterygians, like Fishes, had this advantage over Whales, that their stern-propeller could have the form best adapted for a swift straightforward course through the water.[1] The horizontality of the tail-fin of the Whale tribe relates to their need, as large-brained, warm-blooded air-breathers, to have easy and speedy access to atmospheric air. Without the means of displacing a mass of water in the vertical direction by such broad tail-fin the head of the Whale could not be brought with the needed rapidity to the surface for the purpose of breathing. Nevertheless the Cetaceans are restricted to their element as closely as Fishes, and perish almost, if not quite, as soon when cast ashore, whilst the Ichthyosaurs were less limited in regard to medium, and had a power upon dry land which neither of the other aquatic vertebrates enjoy.

That our Sea-lizards occasionally sought the shore is to be inferred from the strong inverted osseous arch supporting their fore fins, spanning across the chest from one shoulder-joint to the other. In structure this arch closely resembles that in a group of aquatic Mammals (*Ornithorhynchus*), which similarly surpass *Cetacea* in having a command of both land and water, although, by their low position in the mammalian class, they have closer alliance to the *Reptilia*.

There is reason to infer, from examples of diminutive Ichthyosaurs fossilized within the abdominal cage of larger ones, and with the snout directed toward, or partly protruding from, the pelvic outlet, that they were ovo-viviparous and, as a rule, uniparous, reptiles.[2] Others may have sought the shore for sleep or copulation, and have been enabled, by reaction

[1] "Note on the Dislocation of the Tail at a certain point observable in the Skeleton of many Ichthyosauri," 'Trans. of the Geological Society,' 2nd series, vol. v, 1838, p. 511, pl. xlii.

[2] As first shown in the specimen of Ichthyosauri from the Lias of Boll, described and figured by George Friedrich Jäger, op. cit., tab. i, fig. 4; subsequently noted by Quenstedt in specimens in the Tübingen Museum; also by Channing Pearce ('Report of the British Association,' 1874).

of their large and strong fore paddles against the scapular arch, to have crawled or dragged themselves along with the belly resting on the ground.

In outward form an Ichthyosaur (Pl. XXVIII, fig. 1) resembled a huge predatory abdominal fish, with a longer tail and smaller or shallower tail-fin; scaleless, moreover, being clothed by a smooth, probably finely wrinkled, skin,[1] something like that of the whale-tribe.

The mouth was wide and the jaws long, armed, as a rule, with numerous pointed and, in some species, trenchant teeth. Masses of comminuted bones and detached ganoid scales of coeval fishes have been found within the costal cage of the fossil specimens in the situation where the stomach may be judged to have have been. Small, hard, and undigested bodies, containing fish bones and scales, and bearing impressions of the folded surface of the intestinal membrane, have received the name of "coprolites."[2]

Such were the air-breathers which governed the seas of our planet from the Liassic to the Cretaceous period inclusive. At the later epoch the Ichthyopterygians became extinct, and appear to have been superseded by the Mosasaurians. In these the vertebræ have become procœlian; their modified dentition both as to position and attachment is continued on in existing Lizards, but the limbs were fins. The transition, if there was such, is, however, abrupt, and the links are, as yet, unknown which connected the Tertiary cetaceous Zeuglodonts with antecedent whale-like reptiles.

The Cretaceous *Ichthyosaurus campylodon*[3] retains the characters of its order as definitely as they are shown in the species of the Muschelkalk or Lias; and the commencement of this type of Reptile seems to be as abrupt as its close. Much remains to be, and may be, discovered indicating the antecedent forms which linked on more closely the *Ichthyopterygia* with earlier air-breathing vertebrates. But with later ones there is no evidence of transitional alliance; they seem to have passed away under the type of structure which I next proceed to explain as far as study of the fossil remains has made it known to me.

B. Osteology.

a. Bones of the Trunk.—In the vertebræ (Pls. XXI and XXII), according to the regions of the column, are to be noted: the centrum (*c*) neurapophyses (*n*), neural spine (*ns*), pleurapophyses (*pl*), hæmapophyses (*h*), hæmal spine (*hs*), zygapophyses (*z*, *z'*), diapophyses (*d*), parapophyses (*p*), and hypapophyses (*hy*). Some of these are autogenous, others exogenous parts.

[1] "Description of some of the Soft Parts with the Integument of the Hind Fin of the Ichthyosaurus, &c.," 'Trans. of the Geological Society,' 2nd series, vol. vi, 1840, p. 199, pl. xx.

[2] Buckland (Dr. Wm.), "Discovery of the Fæces of the Ichthyosaurus," 'Trans. of the Geological Society,' 2nd series, vol. iii, 1835.

[3] 'Monograph on the Fossil Reptilia of the Cretaceous Formations' (Palæontographical Society's volume, 4to, 1851).

The centrum is more or less antero-posteriorly compressed (Pl. XXII, figs. 1 to 7, 9, 14), with concave terminal articular surfaces (ib., fig. 6) not intercommunicating; on each side of the shallow myelonal canal (Pl. XXII, figs. 2 and 4, *m*) is the deeper, usually triangular, articular surface (*np*) for the neurapophyses (*n*). These, in each vertebra, converge, and, save in the atlas (Pl. XXI, fig. 1, *n*), coalesce at their summits with each other and with the neural spine (ib. figs. 2, 3, 4, *n*, *ns*). In most Fishes the neural arch coalesces with the centrum, as in Cetaceans; its separate state is a saurian, chiefly crocodilian, modification; it is such in the Ichthyosaurs, and adds to the power of inflecting the spine vertically, as in the specimen (Pl. XXIX, fig. 2).[1]

Most of the neurapophyses interlock by means of coadapted zygapophyses (Pl. XXI, fig. 6, *z*, *z'*). The hæmapophyses are developed beneath the abdominal ribs (ib., fig. 2, *h*, *h'*,) and beneath the bodies of most of the caudal vertebræ (ib., figs. 4, 5, *h*); they are always distinct from their centrum (*c*), and do not coalesce below with each other, or with a hæmal spine. The hypapophyses remain detached in the first two or three vertebræ (ib. fig. 1, *hy*), and have advanced to the interspace between their own and the antecedent centrum. That of the atlas (Pl. XXIII, fig. 5, *hya*) is wedged between it and the basioccipital (*o*); that of the axis (ib., *hyx*) between it and the atlas, and so on (ib., *hy*, 3). Conybeare, who first noticed this structure, describes it as follows:—"We have only seen the inferior piece or body (if it can be so called) of the atlas; and the odontoid process (which in all reptiles forms a distinct piece) of the axis; they very nearly resemble those of the turtle."[2]

In the trunk the centrum of the atlas (Pl. XXIII, figs. 2—5, *c a*) is the most modified of that series of vertebral elements. Its fore surface (ib., fig. 2) presents at its upper two thirds a concavity (*c a*), occupying the medial two fourths of its transverse extent, the cavity gradually changing to convexity (*b*) in the lateral fourth. Beneath this smooth concavo-convex articular surface is a rough, flat, triangular surface (*t*), inclining from its upper base backward. The upper joint-surface (*c a*), is for the basioccipital (Pl. XXIII, figs. 1, 2, fig. 5, *o*, in dotted outline), the lower one (*t*), is for the hypapophysis (Fig. 5, *hya*). The hind surface of the atlantal centrum (Pl. XXIII, fig. 4) is flat, and with

[1] More extreme and abrupt vertical flexures, shown in two specimens in the British Museum, may be posthumous, due to disturbance of the decomposing carcase prior to final burial in the Liassic mud, in and with which the skeleton subsequently became petrified.

[2] 'Trans. Geol. Soc.,' vol. v, 1821, p. 574. The homology of the "odontoid process" as the "centrum of the atlas," and that of the anthropotomical "body of the atlas" with the hypapophysial part of that vertebra, is shown in my "Description of the Atlas, Axis, and Subvertebral Wedge-bones in the Plesiosaurus," 'Annals and Magazine of Natural History,' vol. xx, 1847, p. 217, figs. 1—6.

In 1835 Sir P. de M. Grey Egerton communicated to the Geological Society his discovery of not only Conybeare's "inferior piece of the atlas," but the homotypal parts of the two succeeding vertebræ ('Proceedings of the Society,' vol. ii, No. 41, p. 192), and subsequently gave a detailed description, with figures, of these parts under the name of "subvertebral wedge-bones;" 'Trans. Geol. Soc.,' 2nd series, vol. v, 1836, p. 187, pl. xiv.

a few feeble ridges at its peripheral and commonly lower third part. It is rare to find this element unanchylosed with the succeeding centrum (ib., fig. 5, *c x*). The neural surface of the atlantal centrum (ib., fig. 3) is divided equally between the medial quadrate tract (*m*) for the myelon,[1] and the lateral subtriangular depressions (*n p*) for the neurapophyses. The length or fore-and-aft diameter of the atlantal centrum is usually relatively less than in the trunk- or tail-vertebræ of the same individual. The neurapophysial surface bends down upon the side of the centrum, forming a prominence (fig. 5, *d*) on its upper part, representing the diapophysis ; beneath this, with a non-articular interval, projects a low obtuse parapophysis (ib., *p*).

The neurapophyses of the atlas (fig. 6, *n*), as far as I have been able to infer from this commonly mutilated or much disturbed part of the fossil skeletons, were not united together atop, or there developed into an exogenous spine, but retained their distinctness, like their antecedent homotypes the exoccipitals (Pl. XXVI, fig. 1, 2). In the best preserved specimen each atlantal neurapophysis is bent back at the middle of its length, the upper compressed portion overlapping the fore part of the base of the neural spine of the axis, as shown in Pl. XXIII, fig. 6.

Of the existence of the atlantal pleurapophysis (Pl. XXIII, fig. 5, *pl, a*), each being joined by a bifurcate proximal end to the di- and par-apophyses of the centrum, there is better evidence. Such rib was short, directed outward and backward ; and is unconnected, distally, with any hæmapophysis (Pl. XXI, fig. 1, *pl*).

The hypapophysis of the atlas (Pl. XXIII, fig. 5, *hy, a*, and Pl. XXVII, fig. 2) is an irregular triangular robust ossicle, smooth and convex on its inferior and free surface, with the opposite articular surface divided into three facets. The anterior of these (ib., fig. 2, *a*) is smooth and concave, completing, with the concave part of the atlantal centrum, the cup for the basioccipital ball ; an almost flat rough tract (ib., *b*) next below articulates synchondrosaly with the corresponding rough surface of its centrum. Beneath this is a smaller flat roughish surface (ib., *c*), sloping backward from the one above, for articulation with the succeeding hypapophysis. Such are the complex characters of the first trunk-vertebra of *Ichthyosaurus*.

The centrum of the second vertebra (Pl. XXIII, fig. 5, *cx*, and Pl. XXVII, figs. 3, 4, 5), has a flattened, roughish, anterior surface (fig. 4), like the posterior one of the first vertebra, with which it sooner or later coalesces. The hind surface of the axis-centrum (fig. 5) is more deeply and entirely concave, with a sharpish circumferential margin. On the upper surface of the centrum (fig. 3) the myelonal surface (*m*) is similar in size and shape to that of the atlas, but is shallower. The neurapophysial surfaces (*n, n*) are less excavated, and the diapophysial productions (fig. 4, *d, d*) upon the sides of the centrum are more prominent, better defined as processes. The same may be said of the parapophyses (ib., *p, p*), which project close to the fore border of the side surface and show a more distinct facet for the head of the axial rib than do those of the atlas. The

[1] ' Spinal marrow,' ' spinal cord,' of ' Anthropotomy.'

length of this rib is a little more than the vertical diameter of the centrum. The lateral surfaces of the centrum of the axis-vertebra are antero-posteriorly concave, of greater extent behind the rib-processes; vertically they describe a convex curve converging from each side to an inferior medial ridge. This ridge is interrupted, anteriorly, as if that end had been obliquely cut off, forming a roughish subconcave facet for the hind half of the base of the second or axial hypapophysis (Pl. XXIII, fig. 5, *hy, x.*) This element is barely half the size of the one in front, is conical, the apex downward; the base is divided into the surfaces respectively joined to the contiguous hypapophysial facets of the atlas and axis. The neurapophyses converge as they rise and coalesce to form the base of a neural spine (Pl. XXIII, fig. 6, *n s*), the antero-posterior extent of which equals the height—a proportion which distinguishes that part of the second vertebra. Postzygapophyses (ib., *z*) are developed from the base of the spine which overlap and articulate with the prezygapophyses (*z*) of the third cervical vertebra.

Thus, at the fore part of the vertebral column, the neural arch presents the three following modifications:—In the atlas the neurapophyses remain distinct and develop neither post-zygapophyses nor neural spine; in the axis they coalesce, develop the post-zygapophyses and a lofty spine, broader than those in the succeeding vertebræ; the neural arch of the third cervical develops both pre- and post-zygapophyses (Pl. XXIII, fig. 6, *z, z*) and a neural spine (*ns*), subcompressed like that of the axis, but narrower antero-posteriorly: in both vertebræ the neural spine inclines rather backward.

The above descriptions and figures are from an immature specimen of *Ichthyosaurus longifrons.*

In the vertebræ along about a third or more of the trunk, the neurapophysial surface is continued on to the diapophysial process (Pl. XXII, figs. 1—3, *np, d*). This process next becomes distinct (ib., fig. 4, *d*); and, as the parapophysis continues to be developed, the presence of the pair of tubercles, *d, p*, near the fore margin of the side of the centrum characterises that part as far as the fortieth or forty-fifth vertebra in *Ichthyosaurus communis.* In this course both processes gradually descend (ib., figs. 5, 7, *d, p.*), but the diapophysis more rapidly, until it coalesces with the parapophysis, forming therewith an oblique ridge or rising. In the caudal vertebræ the ridge gradually contracts to a rounded tubercle (ib., figs. 9, 11, *d, p.*), and finally disappears at about the eightieth vertebra (ib., fig. 14). At this part of the column, in *Ich. communis*, the abrupt bend or dislocation of the caudal series commonly occurs; and here three or four of the centrums become more compressed than either those that precede or those that follow them, and their lateral margins are raised, as if by forcible compression.

The neurapophysial facets become detached from the diapophyses (*d*) by contracting in breadth, and take the form of narrow longitudinal grooves (Pl. XXII, fig. 4, *p*), bounding laterally the myelonal surface (*m*). This surface sinks a little deeper into the centrum as the vertebræ recede in position, and in the caudal region it contracts both vertically and laterally, until it loses definition in the extreme vertebræ.

The articular bases of the neurapophyses undergo corresponding modifications; the joint-surface is subtriangular, somewhat protuberant in the anterior vertebræ; but, after the diapophysis or rib-surface gets independent, that for the neurapophysis becomes longitudinal, narrow, and grooved. The neurapophysis rises, with a slight receding from the vertical position, for a height usually equalling its fore-and-aft breadth; it develops a short prezygapophysis and inclines backward, with a postzygapophysial surface at its under and hinder part. The pair of neurapophyses having then coalesced send upward and slightly backward a subquadrate compressed neural spine, usually twice the height of the the subzygapophysial part or pedicle (ib., fig. 6, *n*) of the neurapophysis, and with gradually augmenting height and antero-posterior breadth as far as the midpart of the trunk. Towards the hind part the spines begin to lose height, but not breadth, until they enter the caudal region, when they gradually decrease in all dimensions, and disappear at or near the bend of the tail. Feeble emarginations at the fore and hind part of the pedicle form or bound the nerve-outlets.

The contour of the centrum (Pl. XXII) varies with the number and position of its lateral processes. At the fore part of the column it is more or less shield-shaped (fig. 3), with the angles of the upper border rounded off; at the hind part, where the rib-processes have descended (fig. 8) or have coalesced (fig. 11, *dp*), the base is below and the apex truncate for the neural arch; further on, where those processes have disappeared, the contour becomes ellipsoid or elliptic, with the long axis vertical.

The centrum is always short in proportion to its breadth and depth, but this varies in different species; beyond the atlas and axis it is always biconcave (ib., fig. 6), but the contour of the concavity varies specifically. In some the sinking begins at the periphery; in others in a feebler degree there; in others a slight and narrow marginal convexity (fig. 3) precedes or leads to the central concavity; in others, again (fig. 8), a peripheral portion of the joint-surface is flat before it sinks into the central hollow; in exceptional instances, the fore and hind concavities blend at a small central perforation, as they do in the Triassic 'Tretospondilia' of the Cape.[1]

The pleurapophyses (dorsal ribs, Pl. XXI, fig. 2, *pl*) are developed, as free movable elements, over a larger proportion of the vertebral column than in most other four-limbed *Reptilia*, extinct or existing (Pl. XXVIII, fig. 1). They commence at the foremost segment as shown in the description of the 'atlas' (Pl. XXIII, fig. 5, *pl*), gain slightly in length on the axis, in a greater degree on the third vertebra, and acquire their extreme length between the tenth and thirtieth (Pl. XXI, fig. 2, *pl*, and Pl. XXVIII, fig. 1); beyond this they shorten, but continue as free elements, though short and straight (Pl. XXI, fig. 4), along a great part of the caudal region; their existence, as such, being attested in detached centrums by the single sessile process (Pl. XXII, figs. 9—11, *dp*) on each side: with the disappearance of the di-parapophysis the ribs cease. All the ribs

[1] 'Quarterly Journal of the Geological Society,' vol. xxxii, p. 43 (1875).

are comparatively slender, commonly subcylindrical; the longer ones, or those of the trunk, are longitudinally grooved on their outer surface (Pl. XXI, fig. 7), as if each rib consisted of two confluent more slender ones.[1] This structure is not common to all the species. A transverse section which I made exposed a small central cavity.

The hæmal or costal arch is complete along the major part of the trunk. Here the hæmapophyses are each in two partially overlapping pieces (ib., fig. 2, *h*, *h'*); they are more slender than the pleurapophyses.[2] The median piece (hæmal spine, *hs*) is transversely extended, symmetrical, slightly produced at its thickest midpart, forward and backward, but more extended laterally, there becoming slender and diminishing to a point. A similar slender piece, pointed at both ends (*h'*), is spliced as it were, to the fore part of each lateral production of the medial piece. A second styliform hæmapophysis (*h*) is similarly adapted to the fore part of the foregoing style; but as it approaches its pleurapophysis it is slightly thickened, and is joined by a truncate end to that of the pleurapophysis (*pl*). Of the five bones which thus constitute the hæmapophysial part of the thoracic-abdominal hæmal arch, the two on each side I regard as a divided hæmapophysis, and the transversely extended medial piece as the hæmal spine, or abdominal "sterneber." A small but strong triradiate hæmal spine ("episternum") closes the dislocated occipital hæmal arch formed by the modified pleurapophyses ("scapulæ") and hæmapophyses ("clavicles").

In the caudal region the centrum, save at the terminal pinnigerous part, shows a small tubercle at or near each of the four angles of the quadrilateral space (Pl. XXII, figs. 9, 12), forming the lower surface, the anterior tubercles (*hy*, *hy*) being the largest. Each has an articular surface, and the contiguous ones of coadapted centrums give attachment to the base of a short and slightly bent hæmapophysis. These elements, of the same pair, converge as they descend, but do not coalesce to form a "chevron-bone," nor is a hæmal spine developed. These inferior or hæmal arches cease on the terminal twenty or more vertebræ; in most of these the centrum is subcompressed, especially where the seeming fracture or abrupt bend (Pl. XXVI, fig. 8) takes place.

b. Bones of the Head.—The results of my studies in the craniology of the species of *Ichthyosaurus*, subsequent to the 'Report on British Fossil Reptiles' of 1839, were given in the 'Hunterian Lectures,' at the Royal College of Surgeons, London, 1855; and in those delivered at the Museum of Practical Geology, Jermyn Street, in 1858.[3] I have found but little to add or alter in the course of subsequent researches in the preparation of the present Monograph.

[1] Clift, 'Phil. Trans.,' mdcccxiv, pl. xix (1814, *Ichthyosaurus platyodon*).

[2] Ib., 'Phil. Trans.,' mdcccxix, pl. xiv (1819, *Ichthyosaurus communis*).

[3] Notes of these Lectures were published in the 'Annals and Magazine of Natural History,' 3rd series, vol. i, 1858, p. 388 *et seq.*

The general form of the skull of the typical species, *Ichthyosaurus communis* (Pl. XXVIII, fig. 1), as in *Ich. breviceps*, *Ich. intermedius*, *Ich. lonchiodon*, and *Ich. platyodon*,[1] resembles that of the Cetaceous Dolphins (*Delphinus tursio* and *Delphinus delphis*). In *Ich. acutirostris* (ib., fig. 2) the beak is produced to the shape of that of a gigantic stork, while *Ichthyosaurus tenuirostris* and *Ich. longirostris* (ib., fig. 3) rival or surpass the *Delphinus* (*Inia*) *gangeticus* in the length and slenderness of the jaws.

The main difference in the Sea-reptiles lies in the restricted capacity of the brain-case, the seeming expanse of the cranium being due to the great depth and breadth of the post-orbital part of the zygomatic arches or outer walls of the temporal fossæ. A more essential departure from the warm-blooded Vertebrates is the persistent individuality of those cranial elements which, though primitively distinct, become blended into single bones in the higher and later developed forms. The Ichthyosaurs further differ from the marine mammals in the great extent of the premaxillary and the small size of the maxillary bones, in the great capacity of the orbits and the circle of sclerotic plates lodged therein, and, finally, in the antorbital vacuities serving as external bony nostrils.

The occipital region of the skull (Pl. XXVI, fig. 1) is of great breadth and of moderate height. In its formation there enter not only the basi-, ex-, super-, and par-occipitals, but also part of the parietals, mastoids, tympanics, zygomatics, prosquamosals, and pterygoids.

The chief feature is the large proportional size of the basi-occipital (ib., 1), the outer surface of which is divided into an articular (Pl. XXV, fig. 1, 1′) and non-articular part (ib., 1). The articular portion is in the form of a hemispheric, convex condyle, in some species showing a subcentral depression, but deriving no contribution from the exoccipitals, and divided from the 'foramen magnum' by a narrow, upper non-articular tract; the lateral tract gains breadth as it descends along the sides of the condyle, below which it shows an extent of two thirds the diameter of the condyle; but this part of the basioccipital, in extending forward, deviates little from the perpendicular, and belongs rather to the hinder than the under surface of the cranium. The upper non-articular part of the basi-occipital, dividing, in the specimen under description, the condyle from the foramen magnum, is one eighth the diameter of the condyle; then come the depressions for the sutural joints with the exoccipitals, a mere crest dividing them. The exoccipitals (Pl. XXVI, fig. 1, 2, 2) are small and reniform; their bases almost meet above the basi-occipital; their obtuse summits are divided by the base of the super-occipital (3), which contributes about a fourth part of the circumference of the foramen magnum (*f*).

The fore part of the basioccipital presents, in some species, a slight notch or groove, as if for the outlet of an Eustachian canal. This canal, in Crocodiles, traverses the basi-sphenoid, close to its suture with the basioccipital.

The basioccipital articulates, below or in front, with the basisphenoid (Pl. XXV, fig. 1, 5)

[1] See CLIFT'S excellent figure in 'Philos. Trans.,' MDCCCXIV, pl. xvii.

laterally with the paroccipitals (Pl. XXVI, fig. 1, 4); but between these and the basisphenoid it joins the mesially inclined hinder end of the pterygoids (ib., 24). The apex of the superoccipital (3) is wedged into the interspace of the hinder bifurcation of the parietal bones (7′), which it underlaps and partly supports; its base forms the upper border of the foramen magnum. The paroccipitals (ib., 4, 4), broadest where they join the basioccipital, contract as they extend outward into a strong triedral bar, which abuts against the tympanic (28), at the interval between the mastoid (8) and pterygoid (24).

The centrum (1), neurapophyses (2), neural spine (3), and parapophyses (4) of the hindmost cranial vertebra are instructively demonstrated by the Ichthyosaurian condition of the 'occipital bone' of Anthropotomy.

The basisphenoid (Pl. XXV, fig. 1, 5) presents, on its under and outer surface, the form of an irregular, subquadrate plate, narrowest behind, where it joins the basioccipital, expanding as it advances, the anterior border presenting a rough, sutural, notched surface, at its middle third, for the presphenoid (9), and a smooth emargination on each side forming the hind border of the sphenopterygoid or 'interpterygoid' vacuities (*s*, *s*).[1] The hinder half of the under surface of the basisphenoid presents shallow rough depressions and feeble risings for muscular attachments, and, like the basioccipital, it is imperforate. Of the alisphenoids I have been unable to determine more than their presence and their small size. The side walls of the brain-case proper seem to have been mainly cartilaginous.

The parietals (7) in most Ichthyosaurian skulls retain their median (sagittal) suture (Pl. XXIII, fig. 1, 7), which usually opens out anteriorly to form the hind end of the 'foramen parietale' or fronto-parietal fontanelle[2] (*f*), the chief part, or whole, of which is bounded by the frontals (11).

The upper surface of the parietals seems, by reason of the aspect of the occipital portion, to be divided by a ridge (*r*) extending from the mastoids (8″), and continued upon the parietals to their mid-suture, into an anterior (7) and posterior (7′) surface. This masto-parietal ridge (8″ *r*) properly bounds, above, the occipital surface, to which the parietals thus contribute about a fifth part of their length above the superoccipital bone (Pl. XXVI, fig. 1, 7′). Anterior to this ridge each parietal slopes to the temporal fossa (Pl. XXIII, fig. 1, T), the parietal surface being divided by a low longitudinal rising continued forward from a posterior convexity into two facets, both of which are concave across. The dividing ridge is overlapped by a postero-mesial angle of the postfrontal (12), between which and the frontal a narrow forward continuation (7″) of the parietal is exposed, which overlaps the

[1] 'Anatomy of Vertebrates,' vol. i, p. 157, fig. 98, *D*, *s*.

[2] "This foramen, or 'fontanelle,' is common in the Triassic *Reptilia*. It is described and figured in *Galesaurus*, *Petrophryne*, *Dicynodon*, *Ptychognathus*, *Oudenodon*, *Kisticephalus*, and *Procolophon*; in the latter it is large. It is wholly 'parietal' in *Kisticephalus* and *Ptychognathus*, in which it is placed far back."—'Descriptive and Illustrated Catalogue of the Fossil Reptilia of South Africa in the British Museum,' 4to, 1876.

hind part of the frontal. The margins of the sagittal suture usually rise into a low ridge, which is continued upon the occipital part (7′) of the parietal. Of this part (Pl. XXVI, fig. 1, 7′) the surface on each side of the mesial ridge is feebly concave, almost flat, laterally overlapped by the mastoids (8″); it seems to rest upon, without sutural junction with, the superoccipital (3). The postero-lateral extension of the parietal (Pl. XXVI, fig. 1, 7 *x*) curves down beneath the mastoid (8) to within a third part of the lower end of that bone, contributing therewith to the upper and lateral parts of the broad occipital surface.

The mastoid (8, 8′, 8″) is a large and strong triradiate bone, the rays inclining forward from the outwardly obtuse centre or body forming the prominence at each postero-lateral angle of the skull. The upper and inner ray or branch (Pl. XXIII, fig. 1, 8″) is three-sided, one facet looking upward, a second backward, the third forward and outward, contributing, with the parietal, to the outer and hinder wall of the temporal fossa (t). The angle at which the anterior joins the superior facet is continued forward upon the ridge (8″*r*), dividing the hinder and upper facets of the parietal bone. The lower mastoid branch (Pl. XXVI, fig. 1, 8) is a broader plate, smooth, and almost flat externally, forming the upper sides of the occipital region, articulating outwardly with the prosquamosal (27′) and tympanic (28), and below with the pointed process of the pterygoid (24), wedged between the mastoid and tympanic, and here overlapped by the paroccipital (4) in its way to abut against the tympanic. The outer branch of the mastoid, smooth and subconvex outwardly (Pl. XXIV, fig. 1, 8′), extends forward to form the hinder half of the upper zygoma, overlapped by the post-frontal (Pls. XXIII, XXIV, figs. 1, 12), and articulated along its lower border with the broad sclerodermal plate ('prosquamosal,' 27′)[1] occupying the interval between the upper and lower zygomata.

The tympanic is abruptly divided into an upper auditory or proper tympanic portion (Pl. XXVI, fig. 1, 28) and a lower articular portion (ib., 28′). The former is a narrow, subcompressed, outwardly subconvex, bony piece, and is wedged between the mastoid (8) and prosquamosal (27′); its hind or mesial border extends from the mastoid junction to articulate with the pterygoid (24); the outer or lateral border is smoothly rounded and concave, forming more than the hinder half of the auditory meatus (*m*). The suddenly expanded, thick, articular portion (28′) joins the pterygoid (24) mesially and the zygomatic (27) laterally, then descends obliquely backward, for an extent equal to the auditory portion, to thicken and terminate in the surface for the articular element of the mandible. This surface is obliquely suboval, convex from before backward, slightly concave transversely at its fore part.

The hyoid, or hæmal arch of the second cranial segment, is represented by a basihyal and by a pair of rib-like bones (Pl. XXV, fig. 3, 38), homologous with the thyrohyals

[1] This osseous plate is described in my "Report on British Fossil Reptiles," 'Reports of British Association,' 1839, 8vo, p. 9, as the "squamous element of the temporal bone;" it is analogous therewith but not "homologous."

in the Crocodiles, which elements they resemble in their small relative size, but are of more simple structure. Each is feebly and regularly bent, the convexity (in the petrified skull) turned towards each other, converging forward to their junction with the small flattened basihyal, which junction seems to have been by much ligamentous tissue. I noted in a fossil cranium of a full-sized *Ichthyosaurus communis* that the hind ends were $4\frac{3}{4}$ inches apart while the fore ends were but $1\frac{1}{2}$ inch apart. The total length of the bone was 4 inches 2 lines; the breadth of the hind end was $\frac{1}{2}$ an inch, that of the mid-part 5 lines. In the *Ich. longchiodon* (Pl. XXXI, fig. 5) each thyrohyal is a fifth part the length of the mandible. The stylohyals appear to have retained their fibro-cartilaginous or cartilaginous tissue, and have consequently disappeared.

The presphenoid (Pl. XXV, fig. 1, 9) is a long, slender, trihedral bone, broadest where it joins, and commonly coalesces with, the basisphenoid (5) and, along the narrower part, with the two lower sides, converging to a median obtuse angle. It divides the long and narrow, pear-shaped interpterygoid vacuities (*s*, *s*).

Of the orbitosphenoids I have no exact knowledge; they may not have been ossified, there is no trace or sign of the lacertian columellar bone near that part of the cranium.

The frontals, or midfrontals (Pls. XXVII, fig. 1, 11), are small, transversely convex in greater or less degree according to the species, curving in toward the mid-suture in most, and bending outward and downward to the obtuse angle intervening between the nasal (15) and the postfrontals (12). At the hind end of the frontal suture each border curves outwardly to contribute their large share to the 'foramen parietale,' then converging and, in some species (*Ich. latifrons*, Pl. XXVII), wholly encompassing it; here, also, as in some other species, the midfrontals distinctly join the postfrontals. In all the species the hind border joins the parietal (7), the fore border the nasal (15). The midfrontals are widely separated from the orbits by the postfrontals and nasals. I have not had clear evidence of their touching the prefrontals, or of the presence of distinct superorbitals. In *Ichthyosaurus latifrons* (Pl. XXVII, fig. 1) the frontal suture becomes obliterated, and the bone (11) is convex lengthwise as well as across.

The postfrontals (ib., and Pl. XXIII, fig. 1, 12) exceed the midfrontals in size. Each extends from a mesial angle outwards, expanding horizontally, and inclining to form its share of the superorbital border; thence the postfrontal is continued backward, bending down to join the postorbital (12′) and prosquamosal (27′), and contracting to a notched and pointed end, which receives and overlaps the fore end of the zygomatic ray of the mastoid (8). The similarity of character in the postfrontal (12) and mastoid (8) is worthy of note in regard to their general homology as cranial diapophyses.

The hæmal or pleurapophysial arch of the third or frontal segment of the cranium is modified to constitute the lower jaw.

In the mandible of *Ichthyosaurus* the articular element (Pl. XXVI, fig. 2, 29)[1] is

[1] Cuvier, 'Oss. Foss.,' v, pt. ii, p. 272, pl. xvi, figs. 4 and 5 (*Varanus*), *d* ('articulaire').

scantly visible in an outside view, being covered by the largely developed and backwardly extended surangular[1] (ib. 30). With this the angular coextends or slightly surpasses behind (ib., 31).[2]

Of both elements the outwardly exposed surfaces (Pl. XXIV, fig. 2), as they advance, gradually diminish to a point; the surangular (30), in *Ichthyosaurus communis*, disappearing between the dentary (33)[3] and splenial (32),[4] in advance of the hinder half of the ramus, the angular (31) terminates between the surangular (30) and splenial (32), as far behind the fore half of the ramus. The hind part of the outer surface of the surangular shows a triangular, almost flat, but feebly concave surface, finely sculptured with linear impressions, converging forwards to the apex of the triangle, and indicative of a muscular insertion. In advance of this part the surface is smooth and feebly convex, gaining in depth by the convex curve of the lower border, and a similar one at the upper border, which feebly simulates a coronoid process. Opposite, or beneath the slender lower boundary of the orbit, the surangular is overlapped by the hinder-jointed end of the dentary (33). An oblique canal opens forward below the coronoid rising, beneath the hind border of the orbit, whence extends forward a channel, becoming shallow and ending beneath the overlapping point of the dentary. The angular (31) gradually diminishes in breadth or depth as it extends forward.

From such views as I have been able to obtain of the inner surface of the mandibular ramus, the articular element (Pl. XXVI, fig. 2, 29), after developing the concavo-convex broad surface for the tympanic, seems to be continued forward as a thinner, deeper plate, corresponding to the 'complementaire' of Cuvier.[5] It, however, develops no coronoid process in Ichthyopterygians, but in some specimens seems to be a detached scale (Pl. XXVI, figs. 2 and 3, 30′), simply applied to the inner surface of the ramus over the line of junction of the surangular and angular elements touching or joining anteriorly the hind end of the splenial.

This element (Pl. XXIV, fig. 2, 32; Pl. XXVI, figs. 3—6, 32) begins behind by a point between the surangular and angular, gains breadth as it advances to become applied to the inner side of the dentary, which it also underlaps and strengthens usually to within the anterior fourth part of the length of that element. The splenial in *Ich. communis* contributes a small part of the outer side of the jaw beneath the anterior pointed end of the surangular.

There is no other indication of lack of outer surface of the ramus than the neurovascular foramen and groove of the surangular and smaller irregular foramina in the dentary.

[1] Cuvier, 'Oss. Foss.', v, pt. ii, p. 272, pl. xvi, figs. 4 and 5 'surangulaire,' *f*.

[2] Ib., ib., 'angulaire,' *e*.

[3] Ib., ib., (*Varanus*), 'os dentaire,' *a*.

[4] Ib., ib., 'operculaire,' *b*.

[5] Loc. cit., p. 272, *c*.

This important element (Pl. XXIV, fig. 2, 33 ; Pl. XXVI, figs. 4—7, 33) is the longest, if not largest, constituent of the composite mandibular ramus ; it seems not to have carried in any species its symphysial articulation with its fellow to actual confluence. It affords for the lodgment of the mandibular teeth at the hinder half or more of that series only the outer wall and more or less of the floor of a broad and shallow alveolar channel, the inner wall being here supplied by the splenial element (Pl. XXVI, figs. 4 and 5, 32). As the dentary advances it supplants the splenial by developing an inner wall, which finally rises so as to exceed in height the outer one (ib., figs. 6 and 7, 33). The inner surface of the outer wall of the dentigerous groove shows feeble vertical ridges, indicative of alveolar compartments, like those seen along the hinder terminal part of the same channel in *Crocodilia*.[1]

On the outer surface of the dentary, a little below the alveolar border, a series of vascular foramina and grooves leading thence forward is seen in most species of Ichthyosaurs; in a few species the same surface is indented by a narrow longitudinal furrow. The longitudinal central vacuity of the mandible or interspace between its several constituents is considerable, as is shown in CLIFT's figure of a transverse section of a ramus.[2]

After comparison of the foregoing structure with the homologous bone in *Reptilia*, I may remark that the mandible of *Ichthyosaurus* differs from that in *Lacertilia* in the minor relative size and backward extension of the 'articular' (29);[3] it resembles more the *Crocodilia* in the major relative size of the angular (31), but exceeds in its proportion and position as forming the angle of the jaw, though it is less produced backwards. It differs from both the Crocodilian and Lacertian jaws in the larger relative size of the surangular, which extends backwards so as almost to conceal the articular from outward view. It resembles the *Crocodilia* in the absence of any coronoid process from a complementary element; also in the larger relative size and length of the 'splenial;' in this character the Monitors depart less than do the Iguanas from the Ichthyosaurs. In the dentary element *Ichthyosaurus* shows the important affinity to *Lacertilia* in the dental groove, devoid of alveolar partitions; but in the rudimentary indication of these there is a resemblance, as before remarked, to the short non-alveolar tract at the back of the dental series in some *Crocodilia*. The mandible of *Ichthyosaurus* notably differs from that of Crocodiles, and resembles that of Lizards, in the absence of the vacuity between the angular, surangular, and coronal elements, and in the presence of the longitudinal series of neurovascular foramina or outlets along the outer side of the dentary element.

In the greater extent of the mandibular symphysis *Ichthyosaurus* differs from both

[1] 'Descriptive Catalogue of the Osteological Series contained in the Museum of the Royal College of Surgeons of England,' 4to, 1853, vol. i, p. 167, Specimen No. 765.

[2] 'Philos. Trans,' 1820, pl. xvi. See also Pl. XXVI, figs. 4 and 5, of the present Monograph.

[3] CUVIER, tom. cit., pl. xvi, figs. 4, 8, 13, *d*.

Crocodiles and Lizards; in these, it is limited to a small part of the dentary element, but in *Ichthyosaurus* it includes both dentaries and splenials, and the 'symphysis dentarii' (Pl. XXV, fig. 2, 33) is to be noted together with the 'symphysis splenii' (ib. ib., 32') in the discrimination of species. Thus, the latter is longer than the dentary symphysis in *Ich. intermedius*, but is shorter in *Ich. communis*, and, relatively, much shorter in *Ich. tenuirostris* (Pl. XXV, fig. 3), *Ich. longirostris* (ib., fig. 2), and other long and slender-jawed kinds.

The vomerine bones are narrow, longitudinal, vertically disposed plates, with their lower margins rarely visible at the interspace of the palatines and pterygoids.

The prefrontal (Pl. XXIV, fig. 1, 14) I, as yet, know only by its external or facial part. This is a narrow, moderately long, bony tract, extending from the postfrontal to near the nostril (*n*), there receiving the upper angle of the lacrymal (73) in a notch, the upper branch of which notch is wedged between the lacrymal and nasal, (15); the lower boundary is bent inwards to form part of that of the orbit. The extensive upper and inner border of the prefrontal articulates with the nasal, the short hinder border with the postfrontal.

The position and relations of the prefrontal in *Ichthyosaurus*, as in some Fishes, instructively illustrate its general homology as an element of a cranial segment distinct from that to which the frontal belongs, of which bone it has been regarded as a mere dismemberment. As the neurapophyses of the nasal segment they lend, in *Ichthyosaurus*, a large share of their longitudinal extent to the support of their neural spine, the nasal bone. The large size of both pre- and postfrontals relates to that of the eye and of the cavity destined to contain it in the *Ichthyosaurus*.

The nasals (Pls. XXIII, XXVII, figs. 1, 15) are the longest and largest bones of the cranium proper, but contribute only a small part to the side face; each sends a pointed process backward into a corresponding notch of the frontal which it partially overlaps. The apex of the process is in contiguity with the parietal; a notch on each side the base of the process receives the anterior part of the frontal; the angle of the outer notch touches the postfrontal. By its outer border the nasal unites with prefrontal, lacrymal, and premaxillary (22). The latter overlaps and conceals the naso-maxillary suture in the species in which such may be traced. The upper horizontal parts of the nasals gradually diminish to a point between the nasal portions of the premaxillaries. The exposed extension of the nasals terminates, in *Ich. tenuirostris*, about as far in advance of the nostrils as the fore-boundary of these is in advance of the orbits.

The palatines (Pl. XXV, fig. 1, 20) are long, slender bones, commencing behind at the anterior notch between the pterygoid (24) and ectopterygoid (25), forming, as each advances, the mesial boundary of the small palato-naris (*p n*). The palatine then extends forward, joining mesially the pterygoid, until this diminishes to a point, when the palatines come into contact or near contact with each other at the midline of the palate. Externally the palatine unites with the maxillary (21), but the suture is hidden by the

underlapping extension of the palatal process of the premaxillary (22), which reaches to the palato-naris.

The maxillary (Pl. XXIV, fig. 1, 21) begins behind, parallel with the anterior third of the orbit, from which it is divided by the slender fore part of the malar (26). As it advances the maxillary expands into a facial, an alveolar, and a palatal plate, articulating mesially with the ectopterygoid (Pl. XXV, fig. 1, 25), and, in advance of the palato-naris, with the premaxillary (22). The palato-alveolar part of the maxillary is divided from the facial part by the outer alveolar wall. The facial part (Pl. XXIV, fig. 1, 21), coming into view beneath the fore part of the malar (26), expands slightly to unite with the lacrymal (13), and, in the species affording the subject of fig. 1, Pl. XXIV, it contributes the middle third of the lower border of the nostril; but, as a rule, it is separated therefrom by the junction of the lacrymal (73) with the premaxillary (22), as in fig. 2. In advance of this the maxillary is overlapped by the premaxillary, which conceals it from view at about the fifteenth tooth, counting forward, in *Ichthyosaurus tenuirostris*. In no species does it support more than about one third of the series of teeth on its own side of the upper jaw.

The premaxillary (Pls. XXIII—XXV, XXIX, figs. 1, 22) is characterised by its great relative length. Its facial part begins behind by an expanded bifurcation bounding anteriorly the nostril; in advance of which the bone gradually expands, overlapping the nasal and maxillary, descending to the alveolar border to form the major part of the upper jaw, and narrowing to the end. The palatal portion (Pl. XXV, fig. 1, 22), long and narrow, is continued backward between the maxillary and palatine to terminate in a point penetrating the palato-naris (*p n*).

The pterygoid (Pls. XXV, XXVI, fig. 1, 24) is also a bone of considerable size, especially length. It begins behind by a triradiate expansion; the outer short subquadrate branch abuts against the tympanic (28); the upper narrower pointed ray is wedged between the paroccipital (4), mastoid (8), and tympanic (28); the inner and longest branch is broad, wedged between the paroccipital and basisphenoid, reaching with its blunt-pointed end the basioccipital. In advance of this triradiate expanse the pterygoid contracts, presenting a concave inner border, articulating with the side of the basisphenoid (5), and a more concave outer border, which forms the inner one of the cavity which was occupied by the gristly petrosal. As it continues to advance, the pterygoid again expands, its outer border forming an angular process, to the fore part of which the ectopterygoid (25) unites; the pterygoid then extends forward and gradually inward (mesiad), decreasing in breadth, and is continued as a long and narrow strip of bone in contiguity with its fellow, bounding anteriorly the long interpterygoid vacuity (*s*), articulating outwardly for one half of its extent with the ectopterygoid, and for the other half with the palatine.

The ectopterygoid (Pl. XXV, fig. 1, 25) is an elongate plate of bone, though less than half the length of the pterygoid; its rounded hind end and much of its mesial margin articulate with the pterygoid, the rest with the palatine, with which it combines

to form the hind boundary of the palato-naris (*p n*). The outer margin contributes to bound the pterygomaxillary vacuity (*y*) posterior to its junction with the maxillary, along which it extends to opposite the fifth upper tooth or thereabouts, counting forwards, and there terminates in a point.

The malar (Pl. XXIV, fig. 1, 26) is a long and slender, moderately bent bar of bone, commencing anteriorly in a point wedged between the lacrymal and maxillary, thence receding to form the lower boundary of the orbit, and expanding to be partially overlapped by the postorbital bone (12′), behind which it terminates as a wedge between that bone and the zygomatic.

This bone (ib., 27) is subquadrate, its vertical equalling its longitudinal extent; the angles are more or less produced. The upper anterior one is wedged between the prosquamosal (27′) and postorbital (12x) bones; the lower anterior one underlaps the end of the malar; the front border articulates with both malar and postorbital, the upper border with the prosquamosal; the hind border is rounded and concave, forming the fore part of the 'meatus auditorius externus' (Pl. XXVI, fig. 1, *m*); the hinder half of the under surface of the zygomatic expands, and is slightly excavated to articulate with the outer and upper part of the expanded articular end of the tympanic (28′).

The lacrymal (Pl. XXIV, fig. 1, 73) forms the lower two thirds of the anterior border of the orbit; it sends off from the middle and inner part of this border a short process protecting the lacrymal orifice. The bone contracts vertically as it approaches the nostril, of which it forms the hind concave border. The upper part of the lacrymal sends a process which fits into a notch of the prefrontal (14), anterior to which it joins both the prefrontal and the nasal. Anteriorly, it unites in some species with the maxillary (ib., fig. 1), in most with both maxillary and premaxillary (ib., fig. 2); its lower and longest margin articulates with the maxillary and malar.

The two supplemental skull-bones in Ichthyosaurs, which have no homologues in Crocodiles, are the postorbital (12 *x*,)[1] and prosquamosal (27′);[2] both are present in Labyrinthodonts. The postorbital is the homologue of the lower division of the postfrontal in those Lacertians (*e. g. Iguana, Tejus, Ophisaurus, Anguis*) in which that bone is said to be divided. The postorbital most resembles a dismemberment of an ascending process of the malar; its lower end overlaps and joins by squamous suture the hind end of the malar; whence it slightly expands, rising to the middle of the back of the orbit, thence, gradually contracting as it curves upward and forward, it articulates with the prosquamosal (27′) and postfrontal (12).

Were the prosquamosal (27′) connate with the zygomatic (27) as in *Chelone*, the

[1] Described as "apparently a distinct and peculiar bone" of the orbit in the 'Report' for 1839.

[2] This is termed "squamosal" in the Lectures above cited (1858), p. 392. The recognised distinctness of this bone in *Ichthyosaurus* inclined me in 1839 to view the zygomatic and squamous parts of the temporal bone of anthropotomy as essentially distinct elements; a view which subsequent extensions of comparison enforced me to abandon.

resemblance to those parts of the Mammalian 'temporal bone' would be close, save that the squamous portion would be removed from the inner to the outer wall of the temporal fossa. The prosquamosal holds the place of the temporal fascia in Mammals, and should be viewed as a sclerodermal ossification closing, in *Ichthyosaurus* as in *Labyrinthodon*, the vacuity between the upper and lower zygomatic arches, such as exists in *Crocodilia*. In *Ichthyosaurus* the prosquamosal (27′) is a broad, thin, flat, irregularly-shaped bony plate, smooth and subconvex outwardly, wedged into an interspace between the postfrontal, postorbital, zygomatic, tympanic, and mastoid bones.

The chief vacuities in the skull are:—In the occipital region (Pl. XXVI, fig. 1), the 'foramen magnum' or neural canal of the occipital vertebra (*n*), the 'occipito-parietal,' (*o p*), and the 'auditory' (*m*); on the upper surface (Pl. XXIII, fig. 1), the 'foramen parietale' (*f*) and the 'temporal fossæ' (T); on the sides (Pl. XXIV), the 'orbits' (*o*) and the 'nostrils' (*n*); on the lower surface (Pl. XXV) the 'palato-nares' (*p n*), the 'interpterygoid' (*s*), and the 'pterygomalar' (*y*)[1] apertures.

The 'foramen magnum' is formed by the basi-, ex-, and super-occipitals, the last having an equal share with the exoccipitals; the basioccipital contributes the least part of any. The occipito-parietal vacuities are larger than in *Crocodilia*, smaller than in *Lacertilia*; they are bounded mesially by the ex- and superoccipitals, laterally by the parietals and mastoids, below by the paroccipitals.

The auditory aperture, or 'meatus' (Pl. XXVI, fig. 1, *m*), is bounded by the tympanic and zygomatic. The tympanic takes a greater share in the formation of the 'meatus auditorius' in many Lizards; in Crocodiles it is restricted to that which it takes in Ichthyosaurs.

The orbit is remarkable for its large relative size and backward position: in the former character the Lizards approach the Ichthyosaurs, in the latter the Crocodiles. The cavity is formed by the pre- and postfrontals above, by the lacrymal in front, by the postorbital behind, and by the long and slender malar below. In Crocodiles, and in most Lizards, the frontal or mid-frontal enters into the formation of the orbit, and in some Lizards (*Stellio*, *Agama*) the maxillary also. In Chameleons, both the frontal and the maxillary are excluded from the orbit.

The external nostrils are not homologous with the single medial one in the Crocodiles, but answer to the parial nostrils in Lizards, and to the supplementary apertures bounded by the nasal, lacrymal, and maxillary bones in the Teleosaurs. In Lizards the lacrymal is usually excluded by the maxillary from the nostril. In *Ichthyosaurus* the nostril (*n*) is a longish triangular aperture, with the narrow curved base behind; it is bounded by the lacrymal, nasal and premaxillary (22), sometimes also by the maxillary bones, and is usually distant from the orbit by less than its own long diameter. Like the orbit, the plane of its outlet is almost vertical.

[1] 'Pterygomaxillary' in Crocodiles and Lizards, 'Anat. of Vertebrates,' vol. i, pp. 156 and 157, fig. 98, *y*.

The interpterygoid vacuity (Pl. XXV, fig. 1, *s*) is a very long and narrow triangular one; its base is behind, and is bounded by the anterior concavities of the basisphenoid. As it advances it is divided for a certain extent by the presphenoidal rostrum; the lateral boundaries are due exclusively to the pterygoids, which, converging, reduce the aperture to a point. In this formation, *Ichthyosaurus* resembles *Iguana*, but in *Varanus* the palatines enter into the formation of the palatal vacuity in question.

The pterygomalar vacuity (Pl. XXV, fig. 1, *y*) may be described as the lower outlet of the temporal fossa; it is bounded laterally by the zygomatic and malar, chiefly the latter bone; posteriorly by the tympanic, anteriorly by the maxillary, mesially by the ectopterygoid and pterygoid; the outer deep emargination of the latter bone relates to the passage of the large temporal muscles for insertion into the mandible. The larger proportion which the maxillary contributes to this vacuity in recent Saurians suggested the term 'pterygo-maxillary,' applied to it in the undereited work.[1]

The palato-nares (ib., *pn*) are relatively smaller than in most Lizards, and are circumscribed by the palatine, ectopterygoid, maxillary, and premaxillary bones. In Lizards the ectopterygoid is excluded from its formation, and the position of the palato-naris is more advanced than in *Ichthyosaurus*. The *Crocodilia* depart widely from the *Ichthyosauri* in their single and backwardly placed palatal nostril.

The 'foramen parietale' (Pl. XXIII, fig. 1, *f*) receives a much smaller proportion, if any, of the parietal bones than of the frontals in its formation (Pl. XXVI, fig. 1).

The upper outlet of the temporal fossa (Pls. XXIII and XXVII, fig. 1, T) is bounded mesially by the parietal, laterally by the mastoid and postfrontal, behind by the mastoid and parietal, in front by the postfrontal; the lateral or outer wall of the fossa is formed by the mastoid, postfrontal, prosquamosal, postorbital, malar, and zygomatic bones.

More or less of the circle of sclerotic plates are commonly preserved in the fossil skulls of *Ichthyosauri*. They are of an irregular, oblong, quadrate form, joined together by squamous or overlapping sutures at their longest sides. The hind part is usually about half the length of the plate, and is very thin, ending in a trenchant border; the front or pupillary corneal border is thicker, shorter, and nearly straight. From this border each plate extends, raylike, outward, for more than half its length, then suddenly bends towards the back of the eyeball, defining and encasing its periphery, and indicating the extreme oblateness of that visual spheroid. In the *Ichthyosaurus communis* I have counted seventeen of these sclerotic plates.

c. Pectoral and Pelvic Arches and Appendages.—The limbs of *Ichthyopterygia*, as the name of the order implies, resemble the fins of Fishes in the number of digital joints or segments, and, in some species, the seeming excess of digits beyond the typical 'five.' With the parial ones of Fishes these Reptilian fins also correspond, the anterior pair with the 'pectorals,' the posterior pair with the 'ventrals.'

[1] 'Anatomy of Vertebrates,' vol. i, p. 156.

The inverted arch[1] supporting the 'pectorals' is detached from the occiput, as in the Plagiostomes; that supporting the 'ventrals' is also detached from the 'sacrum,' but retains the position beneath the vertebræ, which, when coalesced, receive that anthropotomical name. The hinder arch[1] has gained a structure determinative of the homology with the hæmovertebral elements called 'pelvis,' and the limbs so supported are called 'pelvic.'

The pectoral arch (Plate XXVIII, fig. 4) consists of a pair of scâpulæ (51), a pair of coracoids (52), a pair of clavicles (58), and an episternum (46). In some specimens there appears a trace of a pair of precoracoids.

The correspondence with the same arch in *Ornithorhynchus* was pointed out and figured by Clift.[2] I have not seen an *Ichthyosaurus* in which the clavicles were confluent mesially as a single bony arch, resembling the Avian 'furculum;' but such confluence does take place in the full-grown or aged Monotremes. No sternebers succeed the episternum in *Ichthyosaurus* as they do in *Ornithorhynchus*.

The episternum is small; each clavicle exceeds the length of the anterior transverse ray; the medial longitudinal ray or stem does not exceed the transverse portion in extent. The clavicles are powerful bones, pointed at each end, overlying the transverse rays of the episternum, and continued along the anterior border of the scapulæ towards or near to the 'base' or free extremity of those bones; the joints are rough or sutural. The scapulæ are oblong, subcompressed, truncate at the free or basal end, thickened and broadened at the opposite or articular end for the two joint-surfaces of the coracoid and humerus (53) respectively.

The two pairs of limbs (ib., fig. 1, *s*, *p*) have been found in every sufficiently preserved skeleton, and where such fins have been lost their supporting arches or some elements thereof have usually indicated their existence. Of these limbs the anterior or pectoral (*s*) surpass in size, but in different degrees according to the species, the posterior or pelvic (*p*) pair. They appear to be most nearly equal in size in the skeleton, in part restored, of the *Ichthyosaurus platyodon* (Pl. XXXI, fig. 1), but confirmatory evidence of the degree of difference is desirable in regard to this species. The pelvic pair is the smallest relatively in *Ichthyosaurus latimanus*, *Ich. communis*, and *Ich. breviceps*, but the inferiority is nearly the same in *Ich. intermedius* (Pl. XXX, fig. 1).

In all the species the digits are supported by flattened, subquadrate, hexangular, pentangular, transversely quadrate, or rounded phalanges, exceeding in number in each digit that known in any other Reptile, and recalling the many-jointed rays of the pectorals and ventrals of Fishes.

The shorter-snouted species have the greater number of digits, with more and smaller phalanges; as the jaws proportionately elongate the number of digits decrease, and their phalanges become relatively larger and fewer.

[1] The definition of 'girdle' in our Dictionaries is inapplicable to these parts of the skeleton.

[2] 'Philos. Trans.,' MDCCCXVIII, p. 32, pl. ii.

In all Ichthyosaurs the pectoral limb includes a humerus (see the typical restoration, Pl. XXXIII, fig. 1, 53), two antibrachials (54, 55), three proximal carpals (56), and four distal ones (56′), from which the more numerous series of ossicles (57) are continued. I shall here limit the description of this part of the skeleton to the modification presented in the *Ichthyosaurus communis* (Pl. XXVIII, fig. 1, *s*).

In this species the length of the humerus is but one fourth more than its breadth, and this is greater at the proximal than the distal end. The joint-surface of the head of the bone is subconvex, produced outwardly or anconally upon a thick deltoid ridge, subsiding half way down the shaft; there the ancono-thenal compression becomes more marked and is continued to the distal end, which is pretty equally divided into two subconcave, almost flattened, surfaces for ligamentous union with the antibrachials.

Assuming the prone position of the fin, which presents to outside view its anconal surface, as in Fishes, the anterior antibrachial represents the radius (54), the posterior one the ulna (55). Both bones are pentagonal by reason of the truncation of their distal approximated angles, which give lodgment to the proximal angle of the middle hexagonal carpal bone; the radial and ulnar carpals are transversely oblong, and the quadrangular shape is but slightly disturbed by the production of their contiguous borders into the intervals between the midcarpal and the two metacarpals, which it partly supports. The radial and ulnar ossicles of this third series from the humerus are extended transversely; the four of the following series articulate each with its corresponding metacarpal.

The series of three bones (Pl. XXXIII, fig. 1, 56) presents the same relation to the antibrachials as does the proximal row of carpals in *Testudo*;[1] and the series of four ossicles which follows might be homologised with the distal series of carpals in the same number in *Testudo*. In this case the next transverse row of four ossicles, the third from the antibrachium, may be regarded as metacarpals (57). According to this view the radial metacarpal (57), not the ulnar one (57′) supports two digits, and the normal digits in *Ichthyosaurus communis* are thus five in number (I, II, III, IV, V). Each consists of a series of flattened, somewhat transversely extended ossicles, of which I have counted thirty and upwards in the two ulnar digits of the present species; they are rather fewer in the two radial and the mid-digits. But, in addition to these multiplied digital joints there are two superadded marginal series of ossicles; that (I′) on the radial border of the fin begins between the second and third joints of the radial digit, and is continued to near its extremity. The series (V′) along the opposite, ulnar, margin, begins at the interval between the ulnar proximal and distal carpals, and is also continued to near the extremity of the fifth normal digit. These supplementary ossicles are more rounded in shape than the normal phalanges, but, like these, progressively decrease in size to the tapering end of the fin. At first view, apart from the preceding homological analysis of the bones of the fore limb of *Ichthyosaurus*, they seem to show that seven digital series are present in that fin of *Ich. communis*.

[1] 'Anat. of Vertebrates,' vol. i, p. 174, fig. 108, *a*, *d*, *c*.

All are enveloped in one sheath of smooth integument, which is continued beyond the framework to an obtusely pointed end, and likewise extends some way beyond the hinder or ulnar border of the bones, where it seems to have been supported by numerous fine cartilaginous rays unless the appearance be interpreted as due to parallel bifurcate wrinkles of the skin (Pl. XXVIII, fig, 5).[1]

The ilium (Pl. XXX, fig. 5, 62) is an oblong, subcompressed bone, slightly enlarging at the acetabular end to form the articular surfaces for pubis, ischium, and femur; sometimes, also, more slightly expanding to the opposite free flattened end. This part, if attached to any of the vertebræ, would be so by ligamentous or soluble tissue. The length of the ilium does not exceed, usually, that of three contiguous centrums.

The ischium (ib. 63), of minor length, is thickened at the acetabular end, which shows facets for the ilium, the pubis, and its share in the shallow styloid cavity for ligamentous attachment of the head of the femur. The body of the ischium expands, more or less in different species, to its free non-articular border, anterior to which it unites synchondrosally with the pubis. This (ib., 64) is usually a somewhat longer bone; it also expands to join the ischium at its lower end; the opposed borders of the two bones are concave, and inclose a long and large 'obturator' vacuity.

Modifications of these pelvic elements are shown in *Ichthyosaurus communis* and *Ich. latifrons*, and will be noticed in some other species.

The femur (Pl. XXXI, fig. 1, 65) resembles the humerus, but is smaller and usually rather less broad. Its distal end supports two cnemial bones, repeating the shape and relative proportions of the antibrachial ones. To these succeed three tarsal ossicles, which support four series of digital ossicles. But in *Ich. communis* the anterior or tibial series soon bifurcates, and supplementary ossicles are applied to those of the fibular or hinder digit. The shape of the ventral or pelvic fin thus supported is similar to, but relatively less broad (in *Ich. communis*) than, the pectoral one.

The rare illustration given in Plate XXVIII, fig. 5, is of a pelvic fin.

d. Osteological Summary.—At the risk of some repetition the following remarks, the result of such comparisons as I have had time or means of extending over the cold-blooded air-breathers, may not be unacceptable. The comparison with existing *Reptilia* is almost restricted to the Lacertian and Crocodilian modifications.

In Crocodiles the exoccipitals leave an intervening tract of the basioccipital, which thus takes its share in support of the 'medulla oblongata'; in Lizards the exoccipitals meet upon the basilar element, as in *Ichthyosaurus*, but the extinct Reptile differs from both in the exclusive formation, by the basioccipital, of the condyle articulating with the atlas. Such joint in Fishes is afforded by the basioccipital only, but the articular surface, as a rule, is concave instead of convex. The superoccipital is excluded from the foramen

[1] 'Transactions of the Geological Society,' 2nd series, vol. vi, p. 199, pl. xx.

magnum in Crocodiles, but contributes, in Lizards, a share thereto, as in *Ichthyosaurus*. The paroccipital is confluent with the exoccipital in both Crocodiles and Lizards, as it is in Plesiosaurs.[1] It remains distinct in Chelonians as in Ichthyosaurs.

The extension of the mastoid upon the occipital region of the skull gives it an aspect of solidity more like that in Crocodiles than in Lizards; but this is an adaptive conformation, and depends on the need of an extent of bony surface for the implantation of the powerful nuchal muscles mainly concerned in wielding a head produced into long and heavy jaws, beset, as a rule, with formidable teeth; it also relates to the stability of the prow of the Fish-lizard in cleaving the watery element. The occipital aspect of the diverging extensions of the parietals, and the presence of the 'fontanelle,' called 'foramen parietale' in Plesiosaurs[2] as well as Ichthyosaurs, are more decisive instances of the closer affinity of Lizards, than of Crocodiles, to the antecedent marine types of *Reptilia*. No part of the parietal extends upon the occiput in Crocodiles, but this is the case in Plesiosaurs as in Ichthyosaurs.

In adaptive relation to the mandible and its armature I regard the relative size and shape of the tympanic, the number of bones amongst which it is wedged, and the double buttresses extended on each side from the facial to the cranial part of the skull. In these characters the Ichthyosaurs resemble the Crocodiles; but the upper or postfronto-mastoid zygoma and the lower malo-zygomatic one are present in some extinct as well as existing Lizards, *e. g. Rhynchosaurus*[3] and the *Rhynchocephalia*.[4]

In the exclusion of the mid-frontal from the orbit *Ichthyosaurus* differs from the Crocodiles and from most Lizards, but it is in the Lacertian order only that exceptions occur of repetitions of this Ichthyosaurian structure.[5] In the position, construction, and parial character of the external nostrils the Lizards repeat the Ichthyosaurian and Plesiosaurian type, from which the Crocodiles have departed, but the lacrymal is excluded from the formation of the nostril in all Lizards. In the small relative size of the maxillaries, especially as compared with the premaxillaries, *Ichthyosaurus* differs from both Plesiosaurs and Crocodiles, and still more from Lizards: here we have in Fishes the nearest resemblance to the subjects of the present Monograph. Nevertheless, as in *Lacertilia*, the anterior boundary of the external nostril is formed by the premaxillary; and, as the marine *Reptilia*, like the marine *Mammalia*, needed to have the nostrils at or near to the upper part of the head, so, agreeably with the Lacertian type, the premaxillaries, however they might be produced forward, retain in *Ichthyosaurus*, as in *Plesiosaurus*, the posterior relations with their antorbital nostrils.

[1] 'Monograph on the *Sauropterygia*,' Palæontographical Vol. for 1863 (1865), p. 8, pl. iii, fig. 1, 2–4.

[2] Ib., pl. xvi, fig. 1, 7.

[3] 'Trans. Cambridge Philos. Society,' vol. vii, 4to (1842), p. 350, pl. v.

[4] 'Catal. of Osteological Series in Mus. Coll. Surgeons,' 4to, 1853, p. 143, No. 663; and GÜNTHER 'Phil. Trans.,' MDCCCLXVII, p. 32.

[5] In *Chameleo parsoni, e.g.* CUVIER, 'Oss. Foss.,' v, pt. ii, pl. xv, fig. 80.

Both Lacertians and Crocodilians differ from Ichthyosaurs in the connections of the nasal with the maxillary. The Crocodiles resemble them in the inter-premaxillary suture; its presence is an exception in Lacertians, the Rhynchosaurians and Rhynchocephalians[1] again affording such examples; I have found it obliterated in a *Plesiosaurus dolichodeirus*.[2] In the position and formation of the palatal nostrils the Lacertians agree with, whilst the Crocodiles widely depart from, the Ichthyosaurian type. The apertures are distinct or parial in the Plesiosaurs, but are placed far back.[3]

In the structure of the mandible the dentary resembles that element in Lizards, and differs from that in Crocodiles, in being pierced externally by a longitudinal series of nervovascular foramina; it differs, also, from the dentary in Crocodiles in its posterior termination being above instead of beneath the fore end of the surangular. In the amphicœlian Crocodiles the vacuity between the angular and surangular is much reduced in size; it is still smaller in Rhynchocephalians; it is absent in Ichthyosaurs, as in Plesiosaurs[4] and most Lizards.

In the conformation of the posterior angle and the robustness of the articular extremity of the mandible the jaw of *Ichthyosaurus* more nearly resembles that of the Crocodiles than of the feebler Lizards, but in the mandibular structures indicative of affinity these latter existing Reptiles manifest their closer connection with the *Ichthyosaurus*. This is conspicuously seen in the absence of distinct alveoli and the lodgment of the teeth of both upper and lower jaws in a continuous open channel, the inner wall of which, in the mandible, is in a large proportion contributed by the splenial element. But the cement-clad base or root of the tooth seems not to become anchylosed to the alveolar tract or groove in *Ichthyosaurus*, but to remain free, till shed, as in Crocodiles. Although a portion of the pulp-cavity may persist in the fully developed tooth after the base or root becomes consolidated by a mass of interblended osteodentine and cement, into this mass the crown of the successional tooth presses, and occasions a cavity by absorption.[5] In no case have I found evidence of this successive supply of new teeth in the Triassic or Permian Theriodonts: herein differs their dentition from both Crocodilian, Dinosaurian, Lacertian, and Enaliosaurian *Reptilia*.

In most Lizards the hyoid bones present modifications which relate to the size and uses of the thick, or long, and commonly bifurcate, tongue. In *Ichthyosaurus* the apparatus is reduced to the same number of pieces as in the Crocodile, in which it is less

[1] Monogr. cit., pl. xvi, fig. 1, 22. "On the Affinities of Rhynchosaurus," 'Annals and Mag. of Nat. History,' iv, 1859, p. 237.

[2] Monogr. cit., pl. iii, fig. 1.

[3] Ib., pl. xvi, fig. 2, *r*, *r*.

[4] Monogr. cit., pl. ii.

[5] 'Catalogue of the Fossil Reptilia and Pisces in the Museum of the College of Surgeons,' 4to, 1854, p. 40, Nos. 139, 140. In No. 141 I point out that in some of the teeth "the pulp-cavity has been obliterated in the crown as well as in the base of the tooth." See 'Quarterly Journal of the Geological Society' for May, 1879, pp. 189 and 199.

subservient to the support and movements of the tongue than to the mechanism for defending the larynx and pharynx from the entry of water during the struggles of a submerged prey, when the mouth of the air-breathing destroyer is necessarily exposed to the free ingress of the aquatic medium. The condition of the hyoid apparatus in the *Ichthyosaurus* indicates that its tongue may have been but little better developed than in the Crocodile, and, since the Ichthyosaur obtained its food under the same circumstances which necessitate the hyoid and lingual modifications in the Crocodile, it may be inferred that the hyoid arch was physiologically related to the working of a similar valvular apparatus for defending the orifice of the air-tube from the water admitted into the mouth during the capture of the fishes, the remains of which have been found in the region of the alimentary canal of the great Sea-lizards.

The modifications of cranial structure of the known kinds of *Ichthyosaurus* are chiefly presented by the upper and lower jaws, which become elongated and attenuated in degrees exemplified by the species next to be described. With these modifications are associated increase of number with decrease of size of the teeth, and their total disappearance, finally, as in the Ichthyosauroids of the upper Jurassic beds of Wyoming and some other American localities. For these edentulous Ichthysaurs, their discoverer, Prof. Marsh, has proposed the generic name *Sauranodon*;[1] it is probable that, as in the case of *Cetacea*, showing minor modifications than do the toothed *Ichthyopterygia*, other generic terms for some of these species may be proposed.

C. Species.

a. Ichthyosaurus breviceps, *Ow.*, Plate XXIX.

In the skeleton of this species (Pl. XXIX, fig. 2) the skull is almost equally divided between the antorbital part and that behind; it is about one sixth the length of the entire body, as represented by the vertebral column. This includes, in the specimen figured, 125 vertebræ, of which 46 lie between the skull and pelvis. The neural spines of such trunk-region are lofty, equalling along its major part the vertical diameter of the rest of the vertebræ taken from the base of the spine. The intervals between the spines are very narrow. The centrums are largest at and near the pelvic region. The fore fin has five normal digital series, with smaller supplementary ossicles along both fore and hind borders; it is twice as long and as broad as the hind one.

The specific characters are more fully exemplified in specimens of the skull of larger individuals, which show that the proportions of the rostrum to the rest of the skull in the smaller skeleton may be due to nonage, but the cranial conformation is the same.

[1] 'American Journal of Science,' vol. xvii, p. 85, January, 1879; ib., vol. xix, p. 169, February, 1880.

The skull with the right side shown in profile (Pl. XXIX, fig. 1) was discovered in the thiek Liassic Limestone, ealled "Broad Ledge," at Lyme Regis; and, as usual with such fossils from this loeality, is somewhat eompressed.

The length of the mandible is 3 feet $7\frac{1}{2}$ inehes; that of the upper jaw from the fore part of the orbit is barely 2 feet; and from the fore part of the nostril is 1 foot $4\frac{1}{2}$ inehes. These proportions indicate the eharaeter of the skull whieh suggested the specific name.

The speeies whieh *Ichthyosaurus breviceps* is thus shown to have approaehed in size is *Ich. platyodon*, Conybeare; but, like *Ich. trigonodon*, Theod.,[1] it had fewer and proportionately larger teeth.

In the portion of the upper jaw in advance of the nostril of a well-preserved skull of *Ich. platyodon*, the number of teeth is thirty; whilst in *Ich. breviceps* they do not exeeed eighteen. In a corresponding extent of the lower jaw of *Ich. platyodon* the number of teeth is thirty-two; in that of *Ich. breviceps* it is twenty-two. The length of the skull from the back of the orbit to the fore end of the upper jaw, in *Ich. breviceps*, is three times and two thirds that of the long diameter of the orbit; in *Ich. platyodon* the length of the skull from the baek of the orbit forwards is four times and one third that of the orbit in one speeimen, and four times and a half that of the orbit in a larger speeimen; the size of the eye and of its bony eavity not augmenting, apparently, *pari passu*, with that of the general bulk of the animal. The sclerotic plates, thirteen in number, have been eompressed from within at the side opposite to that exposed, and the parts whieh were abruptly bent upon the midpart of the eyeball have been pushed into line, and fractured at the bend with the fore parts of these plates.

The mandible shows a specifie variety in the proportions of its constituent elements. The angular (Pl. XXIX, fig. 1, 31), which in *Ich. platyodon* has less depth, and in *Ich. communis* much less depth than the surangular, opposite the baek part of the orbit, has in *Ich. breviceps* greater depth, and it extends further forwards, viz. within nearly one fourth of the fore end of the ramus, instead of terminating within one third (*Ich. platyodon*), or before it reaches half way to that end (*Ich. communis*).

The maxillary is excluded from the external nostril by the junetion of the premaxillary (22) with the laerymal (73). The malar (26) extends further forward in a slender pointed form, in advance of the orbit, between the lacrymal and maxillary (21). The hinder expanded sutural border of the nasal (15) is sculptured by some strongly marked ridges and grooves.

The swollen base of the tooth is impressed by longitudinal grooves, fewer in the upper (ib., fig. 3) than in the lower ones (fig. 4); the enamelled crown shows finer longitudinal lineations, and the fore border is slightly trenchant. The crown is relatively longer and more slender than in *Ich. trigonodon*, and less eompressed than in *Ich. platyodon*. The

[1] And. Wagner, 'Beiträge zur Arten von Ichthyosaurus,' 4to, 1851, p. 34, tab. xvi, figs. 3—6.

teeth come nearer in character to those of *Ich. communis*, but are relatively larger, and fewer in a given extent of the jaws, than in that species.

In all the characters above defined as differentiating the present species from those with which it is compared, and to which it makes the nearest approach in the Ichthyosaurian series, the skull figured as that of *Chiroligostinus* in plate 3 of Hawkins's 'Great Sea Dragons,' fol., 1842, agrees with *Ich. breviceps*, and the name might be adopted were it not applied by that author as a synonym of *Ich. platyodon*. Besides the Dorsetshire locality above named, *Ichthyosaurus breviceps* has been discovered in the Lower Lias in the neighbourhood of Brownish, Glastonbury, Somersetshire, in the Zone of *Arietites Bucklandi*.

b. Ichthyosaurus communis, *Conybeare*. Pl. XXIV, figs. 2, 5, 5′; Pl. XXVIII, fig. 1; Pl. XXX, figs. 3, 4, 5.

The name was suggested by the evidences of this species being the most numerous that, at first, came to hand; but subsequent acquisitions seem to show another species to have a better claim, at least in the locality of the Lias formations in the South-west of England.

In *Ichthyosaurus communis* the length of the skeleton is about five and a half times that of the skull, and the length of the 'snout,' or upper jaw, anterior to the orbit, is three and a quarter times that of the orbit

Of great breadth posteriorly, the skull narrows to the fore part of the orbits, thence the upper jaw contracts rapidly, afterwards gradually, to the anterior almost pointed end. As it advances the upper jaw becomes subcompressed. In profile, after the concavity due to the sinking of the cranium anterior to the orbit, the line goes straight to near the end of the upper jaw, where it rapidly sinks to the alveolar border.

The chief characters of the present species are afforded by the teeth and the pectoral paddles.

The teeth (Pl. XXIV, figs. 5, 5′) are more numerous and smaller than in *Ich. breviceps*, but, in comparison with the majority of the known species, are proportionately large. They have an expanded or ventricose root, contracting to a conical, slightly aduncate crown, with a subcircular transverse section. The apex is subacute, but there is no coronal trenchant margin; the enamel is impressed by fine longitudinal grooves, with intervening ridges. These finer ridges are somewhat abruptly divided from the coarser ones of the root by a smooth tract marking the base of the enamelled crown. Viewed in the series the teeth seem to taper less regularly, often more quickly, to the apex than in other species. The upper jaw bears on each side from forty to fifty teeth, of which sixteen or eighteen may be implanted in the maxillary bone, the rest in the premaxillary. Each ramus of the mandible may support a few teeth more than those opposed to them in the upper jaw.

The midfrontals take the chief share in the formation of the parietal foramen, and are excluded from the upper border of the orbit by the pre- and postfrontals. The sclerotic plates are sixteen or seventeen in number.

The nostril is bounded by a straight line above, contributed by the nasal bone, and by a curved line below, due to the lacrymal and premaxillary. The maxillary is excluded from that opening; it receives the pointed fore end of the malar in a notch; that slender bone forms the whole of the inferior border of the orbit.

In the mandible the surangular extends forward beyond the angular. The dentary elements unite to form the major part of the symphysis, a small hind portion being contributed by the splenials (Pl. XXX, fig. 4, 32'). The symphysis so constituted had, in a lower jaw 2 feet 9 inches in length, an extent of 9 inches.

The vertebræ are shorter, or their centrums have a minor antero-posterior extent in proportion to their breadth, than in some other species (*Ich. intermedius*, *Ich. latimanus*, *e.g.*), but are longer than in *Ich. brachyspondylus*. I have counted forty vertebræ between the occiput and the "sacrum," conventionally so calling the centrum nearest the iliac bones. From this to the end of the tail follow, at least, one hundred vertebræ, of which seventy-five no longer support pleurapophyses. The total number of vertebræ in *Ichthyosaurus communis* may be set down at 140.

The episternum shows no marked specific character. The coracoids have the anterior notch deeper than the posterior one (Pl. XXX, fig. 3). The clavicles are long and strong, applied, as usual, to the fore border of the transverse rays of the episternum and to that of the scapulæ.

The bones of both fore and hind paddles have afforded the description given in the preliminary general account of the Ichthyosaurian skeleton (p. 104).

In the specimen (Pl. XXX, fig. 3), in which the pelvic arch and limb are unusually well preserved, the ilium (ib. figs. 5, 62) is sabre-shaped or moderately curved backwards; in length $2\frac{1}{2}$ inches, with a breadth of 5 lines at the middle. The pubis (64) of the same pelvis is 2 inches 9 lines in length, 1 inch in distal breadth; both fore and hind borders are concave. The ischium (63) is nearly of the same length as the pubis, with a distal breadth of 9 lines, and a deeper concavity of the anterior border. The entire vertical extent of the pelvis is 5 inches.

The length of the pelvic paddle in the subject of fig. 1, Pl. XXXIII, is $4\frac{1}{2}$ inches; that of the femur being 1 inch 7 lines. The extreme breadth of the paddle is 1 inch 10 lines. At this part there are five phalanges in transverse line, that number occurring at the fifth bone from the femur. The midtarsal encroaches further between the tibia and fibula than usual.

The *Ichthyosaurus communis* occurs chiefly in the Lias of Lyme Regis and Charmouth, Dorsetshire; in that of Street, Somersetshire, it is rarer than the *Ichthyosaurus intermedius*. Remains of *Ichthyosaurus communis* have been met with in the Lias near Bristol. This species is associated with *Ich. intermedius* and *Ich. tenuirostris* in the Lias

of Barrow-on-Soar; it occurs, likewise, in the same formation at Stratford-on-Avon. In all these localities Ammonites of the species *Arietites Bucklandi* have been associated with the Ichthyosaurian fossils.

c. Ichthyosaurus intermedius, *Cb.* (Plate XXIV, fig. 7, Pl. XXX, figs. 1 and 2).

In this species the orbits are of moderate size,[1] and the facial portion of the skull in advance equals in length about three times the antero-posterior diameter of the orbital outlet. The teeth (Plate XXIV, fig. 7) are relatively smaller and longer than in *Ich. communis* (ib., figs. 5, 5′); the crown has a narrower base, is more acutely conical, with finer longitudinal striæ, and the root has less prominent ridges. The number of teeth is from thirty-five to forty on each side of both upper and lower jaws.

The entire length of the skeleton is from five to five and a half times that of the mandible.

In the best preserved specimens the number of vertebræ ranges between 130 and 140. In the space between the scapula and pelvic arches there are about forty vertebræ, which may be termed 'abdominal.' The neural spines increase in length and fore-and-aft diameter to beyond the middle of this region, and, by reason of their antero-posterior breadth, they are in contact with each other. The fin-bend of the tail occurs at about the seventy-sixth or eightieth vertebra.

The di- and par-apophyses become confluent at or about the forty-sixth vertebra, and such single 'transverse process,' or tubercle, disappears near the tail-bend.

The ribs are slender, and become flattened and longitudinally grooved along their distal halves. After the fortieth pair, or thereabouts, they become straight, short, rounded, without the groove, and resemble mere 'transverse processes.'

Three neural arches in the subject of fig. 1, Pl. XXX, have been dislocated near the bend of the tail. In these, the neurapophyses are short and confluent, with a transversely broad, quadrate neural spine (Cut, fig. 5), the quadrature being due to an abrupt truncation of the spine.

Fig. 5.
Neural arch, front view.
Nat. size.

Fig. 6.
Caudal vertebra, side view.
Nat. size.

[1] Compare with fig. 3, pl. XXVIII, *Ichthyosaurus longirostris*.

In the pinnigerous part of the column the neural arches (Cut, fig. 6) gradually lose breadth, gain length, and still more gradually lose height, the spine always predominating in the fore-and-aft diameter; the summit equals the centrum in that extent, and the neural spines of contiguous vertebræ touch, but do not overlap.

The vertical contour of the midpart of the centrum, above and below a more prominent convex part, is slightly concave. The borders show the moderate convexity or thickening, relating to the compressed characters of the pinnigerous caudals.

The neurapophyses in the basicaudal region seem not to have coalesced above, and the broad, laterally-impressed, and backwardly-produced part, simulates the half of a truncated neural spine. The short, straight, and inferiorly-situated pleurapophyses continue to be developed to near the tail-bend. The shorter hæmapophyses (Cut, fig. 6) are continued from the pinnigerous caudals to within a third part of the pointed tail-bend.

In the skull of *Ichthyosaurus intermedius* the following characters may be noted.

The under surface of the basioccipital is but slightly excavated anterior to the condyle, and the 'foramen parietale' is almost wholly in a raised part of the hind end of the interfrontal suture. The maxillary is separated from the external nostril by the junction of the premaxillary with the lacrymal.

The sclerotic plates are from fifteen to seventeen in number.

The surangular is deeper, and forms a larger proportion of the outer surface of the hind half of the mandibular ramus than the angular. It terminates or disappears at the usual point between the dentary and splenial, in advance of the angular; it develops on its upper border a small but well-marked coronoid angle bounding anteriorly the concavity under the hind part of the orbit. Beneath this angle or process begins the neurovascular groove, which extends, gradually shallowing, a short way forward. The splenial element begins to show at the lower margin of the ramus about the mid-length of the angular; it unites with its fellow to form the hinder two thirds of the symphysis mandibulæ (Pl. XXX, fig. 2, 32′). The articular piece is brought into view by its partial dislocation backward in the right ramus of the subject of fig. 1, Pl. XXX.

The stem of the episternum equals in length one half of the cross-bar; in receding therefrom it slightly expands and becomes flattened. In one young specimen a median cleft extended a short way forward from the end.

The clavicles are distinct, long, and less strong than in *Ich. communis*, feebly bent, with the concavity behind and within, gradually narrowing to each end, and having a sutural surface beneath and behind, some way along each end; the shorter one engrains with the episternal cross-bar, the longer one with the fore part of the scapula. Of this bone the fore border is straight, the hind one concave through the backward production of the humeral joint; near this the outer surface is slightly excavated. In the coracoid the humero-scapular articulation is of less relative extent than in *Ichthyosaurus communis*. The anterior notch is broader, but is as deep as the hinder one; the intervening tract, or neck, is relatively larger than in *Ich platyodon* or *Ich. tenuirostris*.

The present species has afforded the chief ground of the restoration outlined in fig. 1, Pl. XXXIII. The humerus is marked 53; the radius 54; the ulna 55. The fore border of the radius is entire, not notched. The antibrachium supports, as usual, three ossicles (56), followed by four rather smaller (56′). Regarding these as carpals, they support four metacarpal ossicles (57—57′), from which are continued five longitudinal series of progressively diminishing phalanges. The anterior or radial metacarpal (57) supports two digits, of which the radial may be symbolised as I, the next series as digit II. The three other series, III, IV, V, are supported by their respective metacarpals. Each digit consists of numerous phalanges, progressively decreasing to the end. A series of small supplementary ossicles is applied to the radial border of digit I, and to the ulnar border of the digit V, so that seven ossicles may be counted in the same transverse line along the middle third or fourth of the series. The number of phalanges is, however, less than in *Ich. communis*, and the fin is relatively narrower. The characters of the fore paddle above defined are well shown in specimens from the Lias of Lyme Regis and of Street, in the British Museum.

In the pelvic fin the femuris longer in proportion to its breadth, and the distal expansion is relatively greater than in the humerus. The tibial ossicle of the three tarsals has an emarginate tibial border; the corresponding ossicle or phalanx of the second and third series shows the same character.

d. Ichthyosaurus platyodon, *Cb.* Plate XXIV, figs. 4, 4′; Pl. XXXI, figs. 1, 2, 3.

The skull of *Ichthyosaurus platyodon* (Pl. XXXI, fig. 2), is somewhat longer in proportion to the trunk than in *Ich. communis*. Taking as the trunk the extent of the vertebral column to the pelvic arch, such extent includes, in the subject of fig. 1, one length and a half of the skull, while in *Ich. communis* (Pl. XXVIII, fig. 1) it includes rather less than two lengths, and, in *Ich. intermedius* (Pl. XXX, fig. 1) rather more.

The skull of *Ich. platyodon* is longer in proportion to its breadth than in *Ich. intermedius*. The jaws are stronger from the greater relative depth of the mandible and the less gradual attenuation to the rostral extremity. The orbit is of a full elliptic shape, with less approach to the circular, than in *Ich. breviceps* (Pl. XXIX, fig. 1). It is relatively less than in the long- and slender-snouted kinds. The length of the rostrum anterior to the orbit is three and a half times the longitudinal diameter of that cavity.

The osseous circumpupillary ring includes thirteen sclerotic plates in the subject of Pl. XXXI, fig. 2. The surangular (Pl. XXXI, fig. 2, 30) disappears between the dentary (33) and angular (31). This element similarly disappears in a pointed form between the dentary (33) and splenial (32), beyond the midlength of the ramus.

A dental characteristic of the present species is that which suggested to Conybeare the name *platyodon;* the smooth enamelled crown (Pl. XXIV, figs. 4, 4′) being subcompressed, sharp-edged, and pointed; the longitudinal grooves of the tumid cement-clad root are soon lost upon the coronal base. I have counted 45—45 of these teeth in an upper jaw, and 40—40 in a lower jaw, and have noted that the crowns are more often snapped off than in the smaller species, which may be indicative of the greater violence with which they have been used.

From the occiput to the iliac bones there are forty-five vertebræ; thence to near the end of the tail may be counted seventy-five vertebræ; the total number in the skeleton probably somewhat exceeded 120. One of these vertebræ, from the hinder half of the abdomen, is figured (in the inverted position with the neural surface downwards) in Home's Memoir of 1816.[1] The neural spines are thicker, shorter, and more rounded superiorly than in *Ich. intermedius* or *Ich. communis.* The zygapophyses, especially the anterior ones, are well developed, and the vertebræ of the trunk and basal moiety of the tail are strongly interlocked, though admitting some inflection. The ribs increase in length to the twenty-fifth pair; at the thirtieth pair they begin to shorten gradually, and, after the fortieth pair, more suddenly, becoming nearly straight at the forty-fourth pair. Thence they are continued like long transverse processes articulated by a simple head to the single di-parapophysis, as far as the hundredth vertebra.

The scapula (Pl. XXXI, fig. 3, 51) has a relatively broader humeral end than usual. It is preserved with the corresponding clavicle (ib., 58) in a portion of a huge skeleton of the present species in the British Museum.

The coracoid has a relatively larger or longer scapulo-humeral surface than in *Ich. intermedius*, and has a narrower and deeper anterior notch or emargination than in *Ich. communis;* the ento-sternal margin is rather thicker than usual. I have noted a specimen of this bone from Lyme Regis, of which the long diameter was 8 inches 4 lines, the short diameter 6 inches.[2]

The humerus is notable for its breadth, especially distally, compared with its length. The proximal rounded end, or 'head,' is tuberculate at its circumference, indicative of powerful ligamentous attachments to the scapulo-coracoid joint. The fore margin is more concave than usual. This latter character is still more marked in the radius, which, with the ulna, presents the generic shortness and flatness, with a slight excess of breadth, as compared with most other species. The anterior emargination is present also in the radio-carpal bone (Pl. XXXI, fig. 1, 54), and in the corresponding one in the following series. The next ossicle presents the common pentagonal form. Not more than three series of digital bones are preserved in the subject of figure 1, Pl. XXXI. A few supplemental ossicles are preserved at the radial border beyond the middle of the fin-framework. I have not found evidence of a greater number of pectoral digits in any

[1] 'Phil. Trans.,' MDCCCXVI, pl. xiv.

[2] 'Report,' *ut supra*, 1839, p. 114.

remains of the present species. It seems to have been characterised by long and narrow, but powerful fore paddles.

In the pelvic bones the ilium (Pl. XXXI, fig. 1, 62) presents a straight, flattened, slender form. The ischium (ib., 63) is remarkable for its breadth, especially at its medial end. The pubis (ib., 64) is less expanded there; its anterior border is straight.

The femur (ib., 65) is longer in proportion to its breadth than the humerus; its proximal end shows a large depression, probably for the insertion of a stout ligament. The tibia (ib., 66) presents an anterior emargination, as in the radius (54); the same character is repeated in the two succeeding ossicles at the same margin of the fin-framework. Here, also, but three digital series are preserved, with a few small supplemental ossicles along the fibular border of the fin.

The disposition of the distal ossicles in both pairs indicates that the ligamentous or fibro-cartilaginous uniting medium of their framework may have been more abundant than usual, allowing greater flexibility of the terminal part of the long and narrow paddles of *Ichthyosaurus platyodon*. The least incomplete skeleton of this huge species in the British Museum, the subject of Pl. XXXI, fig. 1, is from an individual of about 20 feet in length; but portions of others—the skull, for example, which may be seen at the Geological Society's Rooms at Burlington House—indicate a total length of the individual so represented, of at least 30 feet.

The Lias of the Valley of Lyme Regis is the chief depository of *Ich. platyodon*, but its remains are pretty widely distributed in the same Mesozoic zone. They have been found in the Lias of Glastonbury, of Bristol, of Scarborough, of Whitby, and of Bitton in Gloucestershire. The Ammonites associated with the bones of the subject of Pl. XXXI, fig. 1, are of the species *Arietites semicostatus*, characteristic of the greyish limestone (Lower Lias) of Lyme Regis.

e. Ichthyosaurus lonchiodon,[1] *Ow.* Pl. XXIV, figs. 6, 6′; Pl. XXXI, figs. 4—7.

This species, which appears to have attained a bulk second only to that of the *Ich. platyodon*, differs in the shape and smaller relative size of the teeth (Pl. XXIV, figs. 6, 6′). They are more slender in proportion to their length than in *Ich. communis* (ib., figs. 5, 5′), and are straighter than in *Ich. tenuirostris*. Their base is cylindrical, less ventricose than in *Ich. platyodon* (ib., fig. 4′), and more finely and regularly fluted than in *Ich. communis*. A smooth boundary divides the base from the enamelled crown, and this is traversed by fine longitudinal grooves converging to the apex. The transverse section of its base is nearly circular; it tapers gradually to the apex, which is nearer the posterior line or contour than the axis of the tooth.

The vertebral centrum has a greater proportional fore-and-aft extent than in *Ich.*

[1] 'Report,' *ut supra*, p. 116.

platyodon; the neural arch and spine have a less vertical, in proportion to the fore-and-aft, extent (Pl. XXXI, fig. 6) than in *Ich. communis* or in *Ich. tenuirostris*. Forty-five of these vertebræ may be counted between the occiput and the pelvis; and as many beyond may be made out in the subject of fig. 4, Pl. XXXI, as brings the number up to 120, but the tail is incomplete.

The length of the rostrum anterior to the orbit (Pl. XXXI, fig. 5) includes little more than three longitudinal diameters of that cavity; it is thus relatively shorter than in *Ich. platyodon*, and it is relatively more slender than in *Ich. intermedius*. The mandible, however, does not partake of this proportion, but is nearly as deep and strong, relatively, as in *Ich. platyodon* (ib., fig. 2). The surangular (30) extends farther forward than the angular (31); both disappear in the usual pointed form. The nostril is divided from the maxillary by union of the premaxillary with the lacrymal. The pair of hyoid elements (cerato-hyals) are preserved *in situ* in the subject of fig. 5; they are cylindrical, almost straight, truncate at each end, which very slightly exceeds in thickness the rest of the bone. Each is about one fifth the length of the mandibular ramus.

The coracoid (Pl. XXXI, fig. 7) shows a deep anterior notch, with only a feeble concave outline at the corresponding part of the hind border of this bone. The clavicle is applied and suturally attached to the lower half of the fore border of the scapula. That border is nearly straight; the hinder one is concave through the backward production of the thickened lower end to contribute to the articular surface for the humerus. The anterior border of the radius and succeeding ossicle is emarginate. The chief phalanges of but three digits are preserved in the subject of Pl. XXXI, fig. 4. The character of the pectoral fin of the present species is probably rightly indicated in the main; and in such essentially tridactyle character *Ichthyosaurus longiodon* may agree with *Ich. platyodon*.

The lower or distal ends of ischium and pubis seem to be equally expanded; both bones are broader than the ilium. The ventral fin has been dislocated and bent backward close to the spine. The homotypal ossicles show the same emargination as in the pectoral fin.

This species has hitherto been found only at Lyme Regis; it appears to be a rarer Liassic Ichthyosaur than the three preceding ones. The skeleton above described was discovered by Miss Mary Anning, to whom the discovery and extrication of many rare and interesting fossils of the Lias of this locality are due.

f. Ichthyosaurus longifrons, *Ow.* Pl. XXIII, figs. 1—5; Pl. XXIV, fig. 1; Pl. XXV, fig. 1; Pl. XXVI, fig. 1; Pl. XXVII, figs. 2—5.

The characters of this species are those in which the subjects of the above plates and

of the general description of the cranial organisation of the genus differ in the specific modifications referred to in other sections of the present Monograph.

From the Upper Lias, with remains of *Ammonites bifrons*, of the Cotteswold Hills. The more complete cranial specimen from the same Liassic zone at Curcy, Normandy, has afforded the subjects of the figures in the plates above cited.

g. Ichthyosaurus latifrons, *Kön.* Pl. XXIII, fig. 6; Pl. XXVII, fig. 1.

In the year 1825 Mr. König, Keeper of the Department of Mineralogy, British Museum, published a series of lithographs of fossils, in a folio form, with brief notices of the subjects, reaching to number 100. Beyond this, names alone are given at the foot of each plate, and No. 250 of plate xix bears that of *Ichthyosaurus latifrons*. It is a very reduced view of a mutilated skull and portion of the vertebral column, with some vertebræ outlined of the natural size. The specimen is stated to have been obtained from Lyme Regis.

Of this specimen a view of the upper surface of the skull is here given of the natural size, in Pl. XXVII, fig. 1. The upper apertures of the temporal fossæ (t, t) are nearly equilaterally triangular in form, the base being external and slightly exceeding the sides, which converge to the cranium proper. The sagittal suture (7) persists, but the frontal one is obliterated, and the midfrontals (11) constitute a single symmetrical bone, which is moderately convex both lengthwise and crosswise.

The "foramen parietale," of a full ovate figure, is formed wholly by the frontal, the apex alone forming the beginning of the parietal suture.

The postfrontal (12) extends upon the coronal suture, and overlaps part of both parietal and frontal bones. The nasal (15) overlaps the fore part of the frontal, and divides that bone from the prefrontal (14). The sides of the skull converge rapidly to the beginning of the snout. A breadth of cranium across the temporal apertures of 7 inches is reduced to 2 inches anterior to the nostrils (ib, *n*).

Additional characters of the present species are afforded by a second specimen from Lyme Regis acquired by the British Museum. It is a skeleton, lacking both ends, but including the trunk, with chief part of the skull and basal portion of the tail, the total length being 4 feet 10 inches. From the occipital condyle to the pelvis it measures 2 feet 6 inches; the length of the preserved portion of the skull is 1 foot 4 inches. In this specimen is instructively shown the sudden slope by which the broad cranium descends into the rostrum. The orbit is correspondingly large, its vertical diameter is 5 inches, its antero-posterior one is $4\frac{1}{2}$ inches. The sclerosteal circle is composed of correspondingly large plates, of which seven are preserved.

The vertical diameter of the base of the rostrum, taken across the middle of the nostril, is but 1 inch 3 lines. The premaxillary is impressed by a longitudinal groove, running about three lines above the alveolar border.

The teeth are long, slender, slightly recurved; six or seven may be counted in an extent of two inches of the alveolar groove. The length of the crown of the best preserved is 6 lines, its basal breadth being 1 line.

In the composition of the mandible the angular element is unusually short; it disappears parallel with the hind border of the orbit. On the other hand, the sur-angular is longer than usual, but its chief character is the continuation of the forwardly-directed nervo-vascular foramen, usually present below the hind border of the orbit, into a groove continued forward, towards the lower border of the ramus, and terminating at a vertical line dropped about a nostril's extent in advance of that opening. A second and narrower longitudinal groove extends along the dentary about two lines below the alveolar border.

The length of the jaws cannot be determined in this or in the typical specimen, their fore end being broken off, but sufficient remains to indicate that *Ich. laticeps* belonged to the long and slender-jawed species, with small and slender teeth to match; and associated, as in *Ich. tenuirostris*, with a powerful fore paddle, supported by comparatively few and relatively large phalanges.

The proportion of the longitudinal to the transverse diameter of the vertebral centrums is contrasted with those of the *Ich. brachyspondylus* in Pl. XXXIII, fig. 6. The neural spines of the dorsal vertebræ are relatively short and with distinct intervals. Thirty-eight are preserved between the scapula and ilium.

The scapula is characterised by the greater relative expanse of its articular end in comparison with the breadth of the body, resembling in this respect that of *Ich. platyodon*. The coracoid has a deep anterior emargination, and a shallow posterior one; the antero-posterior breadth of this bone is 4 inches, the transverse extent is 3 inches. The left coracoid, with the corresponding humerus and a few paddle-bones, have been pushed dextrad and appear beneath the right coracoid, from which the corresponding paddle has been removed.

The pelvic bones of the right side are well shown. The ilium, 2 inches 4 lines in length, is directed obliquely backward and downward; its upper end is one inch in breadth. The pubis, 2 inches 3 lines in length, has a distal breadth of 11 lines; its fore border is almost straight. The ischium, 2 inches in length, has a distal breadth of 1 inch 3 lines. The margin towards the pubis is more concave than the opposed one of the latter bone. The hind border of the ischium is moderately concave.

Compared with the same bones in *Ichthyosaurus communis* the pelvic elements are more robust.

Of the structure of the appendage of the pectoral and pelvic arches, or fins, I have not, as yet, obtained satisfactory evidence.

The fossils which have served in the present section of the Monograph have been obtained from the Lias of Lyme Regis and Charmouth.

h. Ichthyosaurus acutirostris,[1] *Ow.* Plate XXVIII, fig. 2.

This species is so named from the slender, sharp-pointed form of the snout, unaccompanied by such proportions of length as characterise the *Ichthyosaurus tenuirostris* and *Ich. longirostris* (ib., fig. 3).

The length or fore-and-aft diameter of the orbit in the subject of the above plate is 6 inches, that of the part of the skull anterior thereto is 18 inches 7 lines. Both upper and lower jaws are impressed by a deep and narrow longitudinal groove near to and parallel with the alveolar border. The osseous sclerotic part of the eyeball occupies about two thirds of the long diameter of the orbit.

The teeth are intermediate in character and in number between those of *Ich. intermedius* and *Ich. tenuirostris.*

The few trunk-ribs preserved in my present subject are slender, rounded, ungrooved, and have a feebly-produced anterior margin along their proximal fourth.

The mesial border of the coracoid is sinuous, the articular surface for the episternum being better defined and more tumid than usual. The surface of the lateral or outer border for articulating with the scapula and humerus is strongly developed. The length of the coracoid in the specimen described is 7 inches, its breadth $7\frac{1}{2}$ inches.

The humerus is 7 inches in length and $5\frac{1}{2}$ inches in breadth at the distal end. Of the fore paddle three digital series and a small portion of a fourth are preserved, but in such juxtaposition as to leave little doubt as to any considerable part of the fin-bones being lost. These, along the fore or radial border, including the radius, radio-carpal, and succeeding ossicle, are emarginate; the rest have that border entire and moderately convex. After the fifth ossicle from the humerus the subquadrate merges into the transversely oval form. From the inclination of the radial digit toward the middle of the fin, a bifurcation is indicated at about the ninth ossicle from the humerus, and an irregular scattered series of small, full-elliptic, and circular bonelets, may be interpreted as an additional digit to the three normal ones, the more direct continuation of digit II now extending down the centre of the bony paddle. An irregular ulnar series like that on the radial side is partially shown. If there should be lack of osseous evidence of the breadth of the fore fin there is less of its length, which seems to have been two thirds that of the skull, and this is due rather to the size than the number of phalanges. The preserved basal portion of the left paddle repeats the character of the

[1] 'Report,' *ut supra*, p. 116.

corresponding part of the right one above described, and so far confirms the inference as to the specific character of the fins associated with the acuminate one of the skull.

The fossils on which the above species of Ichthyosaurs is founded are from the Lias of Whitby, Yorkshire.

i. Ichthyosaurus tenuirostris, *Cb.* Plate XXIV, fig. 8; Plate XXV, fig. 3; Plate XXXII, figs. 1—6.

The characters which, in 1822,[1] strikingly distinguished the present from the then determined species of *Ichthyosaurus*, were the great length and slenderness of the jaw-bones, suggesting the proportions of those of the Crocodilian gharrial; and which, in combination with the large orbits and low broad cranium, gave to the skull a resemblance to that of a gigantic woodcock (*Scolopax*), with a bill armed with teeth.

The length of the snout is chiefly due to the prolongation of the premaxillaries (Pl. XXXII, fig. 2, 22) and dentaries (ib., 33). The length of the skull anterior to the orbit is somewhat less than four times the antero-posterior diameter of that cavity.

The parietals retain their sagittal suture, the fore part of which recedes in a greater proportion than usual to contribute to the foramen parietale. Their posterior bifurcation is applied, in the occipital region, to the super-occipital, which is broad and arched. The outer end of each parietal prong is obliquely truncate for the suture with the mastoid (ib., fig. 2). This, as usual, forms the blunt but prominent supero-lateral angles of the hind part of the cranium. The midfrontals (ib., 11) retain their suture, their lateral border articulates with the prefrontal (14) and the superorbital, or a forward extension of the postfrontal. This element articulates with the lateral border of the parietal and combines with that bone in forming the upper three fourths of the temporal fossa, the lower boundary of that cavity being completed by the mastoid.

The orbit is bounded behind chiefly by the postorbital. The malar is unusually long, extends from the lacrymal (73) to form the rest of the anterior boundary of the orbit; then, continuing to circumscribe it below, the malar curves with a rather abrupt bend upwards to join the postorbital, and by an oblique suture the zygomatic. This bone is continued obliquely backward to contribute to the external meatus auditorius and to articulate with the tympanic.

The sclerotic plates preserved in the orbit of the subject of fig. 2 bend more abruptly than usual towards the back part of the cavity, suggesting a depressed spheroid form of the eyeball.

The nasal (15) presents the usual connections; the margin which it contributes to the upper part of the nostril (*n*) is slightly convex, encroaching on that opening, which

[1] 'Trans. of the Geological Society,' 2nd series, vol. i.

seems to be rather longer, proportionately, than usual: in the subject of fig. 2 it is $2\frac{1}{2}$ inches in length.

In the composition of the lower jaw, I have noted that the angular element extends a short way in advance of the surangular before disappearing externally. The point of the surangular enters a notch in the hind part of the dentary, about half an inch anterior to a line dropped from the fore part of the nostril. The angular disappears, as usual, between the splenial and dentary, not between the splenial and surangular. The splenials contribute a small proportion to the mandibular symphysis (Pl. XXV, fig. 3, 32′).

The teeth (Pl. XXIV, fig. 8) conform in relative size and slenderness of crown with the slenderness of the bones wielding them. Those at the fore half of the jaws incline more backward than usual, and hardly assume a vertical position in the maxillary and post-mandibular regions. I have counted from sixty-five to seventy on each side of the upper jaw, of which twenty-five, or thereabouts, are implanted in the maxillary. In the lower jaw there are about sixty teeth in each dentary (Pl. XXXII, fig. 2, 33). A few detached teeth in a portion of a large *Ich. tenuirostris* from the Lias at Pyx Hill measure, each, 1 inch 4 lines, the enamelled crown being about a third of that length; the cement-clad root is 4 lines in diameter, rather thicker in proportion than in the smaller-sized specimens of the present species.

The vertebral column (Pl. XXXII, fig. 1) agrees in general length with the characteristic shape of the head. In the best preserved specimens it is nearly four times the length of the skull.

I have counted 156 vertebræ in a well-preserved column of the large specimen from Pyx Hill; in this the pinnigerous part of the tail was two feet in length, and had been bent down in the burial and subsequent petrifaction of the Sea-dragon at almost a right angle to the trunk; this deflected part included sixty centrums, which seemed to be relatively somewhat shorter as well as narrower than those of the trunk. At the bent part of the column the margins of the terminal articular facets were slightly deflected, and markedly raised from the level of the sides of the centrum, indicative of the degree and frequency of flexure at this part. The fore-and-aft diameter of a post-abdominal vertebra in an average-sized Tenuirostral is 13 lines, the vertical diameter being 2 inches 6 lines. The terminal articular surfaces of the centrums are more uniformly concave than in the previously described species. I have not found in *Ich. tenuirostris* more than two hypapophyses at the fore part of the column, one wedged between the basioccipital and the atlas, the other between the atlas and axis. This more simple apparatus for fixing the immediate support of the skull suggests an accordance with the lighter and more slender character of that part. The centrums gradually increase in fore-and-aft dimensions to the pelvic region, and do not begin to decrease in size till about ten vertebræ beyond the part forming the base of the long caudal region.

The ribs soon become long and slender as they recede from the head, and increase in length to near the hind end of the abdomen; thence they shorten less gradually than

usual. Forty-five pairs of the long and regularly-curved ribs show the external longitudinal groove.

The parial fins (Pl. XXXII, figs. 4, 6) show a somewhat less disparity in the size of the pectorals and ventrals than obtains in *Ich. communis* and *Ich. intermedius*. Their framework has fewer and larger bones, and the fore paddle impresses one with its massive proportions compared with the vertebræ. The clavicles are relatively more slender than in *Ich. communis*, but of the usual form, diminishing at the two extremities. The scapula is relatively larger than in *Ich. intermedius*, and is thicker and more expanded at the humeral end; its fore border is moderately concave and longer than the hind one. The coracoid (ib., fig. 3, 52) has a broad neck supporting a large and thick scapulo-humeral articulation; it has a deep and narrow anterior notch, and a shallow posterior emargination. In a well-preserved specimen of the present species, in the Philosophical Institution, Birmingham, the length of the coracoid is 4 inches 5 lines, and the breadth 3 inches; the length of the humerus of the same specimen is 3 inches 10 lines, the breadth of its distal end is 3 inches. The transverse diameter of the radius equals the antero-posterior diameter of the centrums of two of the parallel vertebræ; its anterior margin is notched. The ulna has a corresponding size, with a smaller anterior notch circumscribing with an apposed notch in the radius a roundish vacuity. These bones were anchylosed together and to the humerus in the Birmingham specimen. The 'manus' commences by three transversely oval carpals, of which the radial one is notched, as in the radius; but this character is not repeated, as in *Ich. acutirostris* and *Ich. platyodon*, in the next distal bone, nor is the radial digit bifurcate, as in *Ich. communis* and *Ich. intermedius*. There are but three series of digital bones, with a fourth shorter marginal series of smaller ossicles.

In the hind paddle (Pl. XXXII, fig. 6) the femur, like the humerus, has a longer shaft than usual, and not so proportionally broad a distal end. The tibia is notched anteriorly like the radius, but not so deeply; the corresponding tarsal bone is more feebly emarginate. In this fin, also, there are but three series of digital ossicles.

In the Museum of the British Institution there is a skeleton of *Ich. tenuirostris* thirteen feet in length: it is from the Lias of Lyme Regis, Dorsetshire. Evidences of the same species have also been obtained from the Lias of Stratford-on-Avon, of Bristol, of Street, Somersetshire, and at Barrow-on-Soar, Leicestershire.

k. Ichthyosaurus longirostris, *Ow.* Pl. XXV, fig. 2; Pl. XXVIII, fig. 3; Pl. XXXII, figs. 7, 8, 9.

The specimens in the British Museum, from the Lias of Barrow-on-Soar, on which the present species is founded, and the least incomplete of which is the subject of figure

7, Pl. XXXII, have borne the above specific name in the Public Gallery of the Department of Geology for fifteen years. The description was reserved for the present Monograph, and I regret the unavoidable circumstances which have delayed its communication to the Palæontographical Society.

Reckoning the lost terminal caudal vertebræ according to the guiding analogies I estimate the total length of the animal to include four lengths of the skull. Of this part the length of the rostral extension anterior to the orbit is four and a quarter times the antero-posterior diameter of that cavity: and yet the orbit is relatively larger than in *Ichthyosaurus tenuirostris*.

The teeth correspond in size with the slenderness of their supporting jaws; they are of difficult detection; the best preserved show crowns, as in fig. 3, Pl. XXVIII. With sufficient magnifying power traces of longitudinal striæ are discernible on the enamelled crown; the cemented base is as little tumid as in *Ich. tenuirostris*. In the relative minuteness of the teeth of *Ich. longirostris* we may discern the transitional step to the edentulous Ichthyosaurs described by Prof. Marsh.[1]

I conclude that the present, together with other long- and slender-jawed Fish-lizards, may have preyed in a great degree upon the contemporary Cephalopods with internal rudimental shells as well as on Fishes. The eye in *Ich. longirostris* is proportionately large, like the orbit which the sclerotic circle almost occupies, suggestive of the nocturnal habits of the species; the plates seem to have been not fewer than sixteen in number. The present species, like *Ich. tenuirostris*, is characterised by the large size of the pectoral fin, and that of the ossicles representing the carpals and phalanges of its digits. These, however, are limited in number, as in *Ich. tenuirostris;* the three normal digits (II, III, IV) are instructively conserved, though not terminally entire, in fig. 7, Pl. XXXII. The supplementary ossicles here preserved are, situated as in the tenuirostral species, along the ulnar margin, forming a sort of rudiment of the digit (V), which is normally developed in *Ich. communis* and *Ich. intermedius*.

The scapula, clavicle, and coracoid of the same side as the fin are definite, but dislocated. The coracoid repeats the type of that of *Ich. tenuirostris* so far as having the anterior notch the best marked, but the posterior one is more faintly indicated. The anterior notch (Pl. XXXII, fig. 9) is placed further back, and becomes lateral rather than anterior. The articular prominence is also nearer the hind border of the lamelliform bone.

The radius and radio-carpal bone are notched anteriorly, as in *Ich. tenuirostris*.

The pelvic paddle has the same relative size as in that species, and the same tridactyle structure.

I reckon forty-eight vertebræ between the skull and pelvis; fifty-two vertebræ can be made out in the extent of the caudal region preserved; to which may be added about

[1] "A New Order of Extinct Reptiles (SAURANODONTA)," 'Amer. Journ. of Science and Arts,' vol. xvii, Jan., 1879, p. 85.

a score more for the wanting pinnigerous terminal portion of the tail, which probably has been torn off by predatory assailants of the dead reptile.

Besides the Liassic locality of Barrow-on-Soar, specimens and parts of *Ichthyosaurus longirostris* occur in the zone characterised by *Ægoceras angulatum;* also in the zone of *Arietites Bucklandi*.[1]

l. Ichthyosaurus latimanus,[2] *Ow.* Pl. XXXIII, figs. 2, 7.

This species is nearly allied to *Ich. communis* in the size and construction of the pectoral paddle; but the still smaller proportion of the pelvic one suggested the *nomen triviale*, which is vindicated, also, as a sign of specific difference, by the proportionally shorter and thicker jaws and by the modification of the vertebral centrums (Pl. XXXIII, figs. 2 and 7); in this character the present species differs from *Ich. breviceps*.

Ich. latimanus resembles *Ich. communis* in the ventricose, subobtuse character of the teeth, or, at least, some of the more worn ones, of the twenty-nine which may be counted on each side of both jaws. The articular surfaces of the centrum are concave at the middle third, the rest of the surface to the circumferenee is flat.

In the specimen of *Ich. latimanus*, 6 feet 10 inches in length, and in that of an *Ich. communis*, 5 feet 2 inches in length, the following were the respective dimensions of bones of the scapular arch and its appendage:

	Ich. latimanus.			*Ich. communis.*	
	In.	Lines.		In.	Lines.
Scapula, length of	3	4	...	3	0
Coracoid, antero-posterior diameter .	3	8	...	2	4
Coracoid, transverse diameter . .	3	2	...	2	0
Antibrachials, breadth of . . .	2	5	...	1	7
Length of fore fin, humerus inclusive .	7	6	...	5	0
Breadth of ditto .	3	6	...	2	4

The clavicle is proportionally thicker than in *Ich. communis;* in the skeleton above cited it is 6 inches 8 lines in length.

The head is relatively shorter. In the specimen of which the dimensions are above given the mandible is 1 foot 4 inches in length, while in the *Ichthyosaurus communis* above compared it is 1 foot 5 inches in length.

In a specimen of *Ichthyosaurus latimanus* in the Museum of the Philosophical Institu-

[1] See the classical Monograph, by Dr. Wright, F.R.S., &c., in the volumes of the Palæontographical Society issued in 1878 and 1879.

[2] 'Report,' *ut supra* (1839), p. 123.

tion at Bristol I counted 114 vertebræ; the terminal caudals showed in a greater degree than usual the compressed character indicative of the vertical tegumentary fin.

Parts of the carbonised integument are preserved on the slab of Lias on which lies the above skeleton; faint traces of integument lie above and beneath the deflected caudal vertebræ; a broad patch remains about four inches beyond the last preserved centrum, though not the last of the series. This is the sole direct evidence I have as yet detected of the tegumentary part of the tail-fin. Traces of the abdominal integument appear to be smoother than in the similarly preserved skin figured in Buckland's, 'Bridgewater Treatise.'

If, as has been suggested (p. 86), the pectoral arch and fin relate to occasional reptation on the sea-shore, it may be inferred, from the partial flattening of the articular surfaces of the vertebral centrums, as well as from their proportions, in the present species, characterised as it, also, is by more massive proportions of the pectoral arch and greater relative size and strength of the fore paddles, that it was more littoral in its habits than the majority of these marine Saurians.

Saltford, near Bath, and the Penarth Beds (Rhœtic) of Glamorganshire are among the localities of *Ichthyosaurus latimanus*.

m. Ichthyosaurus brachyspondylus, *Ow*. Pl. XXXIII, figs. 3—6.

This species is founded on vertebral characters, the centrums being shorter in proportion to their height and breadth than in any other that has come under my observation.

In the abdominal centrum, the subject of figures 3—5, Pl. XXXIII, the breadth of the articular terminal surface (ib., fig. 4) is 2 inches 11 lines; the vertical diameter is 3 inches, while the antero-posterior extent does not exceed 11 lines. In a more posterior centrum (ib., fig. 6) in which the diapophysis (*d*) has descended to contact with the parapophysis, the same proportions are preserved with slight diminution of size. In a larger mid-dorsal centrum of this species which I examined in the private collection of Mr. Rose, of Swaffham, the breadth was 3 inches 8 lines, the height 3 inches 9 lines, but the length did not exceed 1 inch 5 lines.

In a collection of fossils from Mid-Jurassic beds in the Province of Moscow, submitted to me by Col. Kiprianoff, in 1853, were centrums showing the same dimensional characters, together with a low medial ridge dividing the under surface, which is, likewise, present in the British specimens. Col. Kiprianoff adopted the name, with my determination, of his Ichthyosaurian specimens, other evidences of which have since been detected and described in a valuable contribution to Russian palæontology by Prof. Trautschold.[1]

[1] Trautschold (Prof. H.), 'Ergänzung zur Fauna des Russischen Jura,' 8vo, 1876, p. 5.

D. Conclusion.

Although a study of the evidences of Ichthyopterygian organisation, of which, and its modifications, as exemplified at the Liassic period, the results are given in the foregoing pages, has left the impression, mainly, of the great additions which wait to reward subsequent cultivators of this field of comparative osteology, I am unwilling to quit it without giving expression to some of the general notions which its cultivation has suggested.

Palæontology has been regarded, if not defined, as including a kind of knowledge of parts, or of structures, in such degree interdependent that, any one being given, others may be deduced as a necessary consequence, such deductions being determinative of the relations of the whole; so far as to give the Knower a power of predicating results, both zoologically, as respects the affinity of the otherwise unknown whole, of which only a part affects the senses, and physiologically, as respects the living powers of the whole and the part such extinct organism played in the sphere of its existence.

This necessary connection and interdependency of the links of structures constitute the essential condition and attractive character of palæontological science. The subject, nevertheless, of the present Monograph, constrains me to submit the question, how far this science of ours has advanced towards sustaining the foregoing definition; in other words, to how much of organic Nature at large, or of particular organisms, it is so applicable.

Let us suppose, for example, that no other part of the petrified frame of an Ichthyosaur had come to our hands than had reached those of Scheuchzer or of Bronn,—a few vertebral centrums, for example, from the hind part of the trunk. Could we have otherwise concluded than they did? Certainly not, had our knowledge of the vertebral structures been restricted to the same parts of the extinct and fossilised animal.

Biconcavity of centrums is a pre-eminently piscine character, but not without exceptions in the class of Fishes, even in that great proportion of the species whose osseous development has advanced to individualised bony segments of the spinal column. Such an exception, *e. g.* we have in the opisthocœlian vertebræ of the Bony Gar (*Lepidosteus*).

But no known kind of Fish possesses vertebral centrums with both upper and lower transverse processes ('diapophyses' and 'parapophyses'). The presence of these in certain of the biconcave vertebræ of *Icthyosaurus*, bespeaks that of ribs having a two-fold articulation with their vertebræ; and such structure of rib implies a body-cage adapted to the movements of expansion and contraction of its cavity, which cavity we infer, therefore, to have contained bags receiving air, and to have had associated movements for the purposes of respiration.

But this function raises the exerciser above the grade of the Fish, and the next ques-

tion of the Palæontologist would be, whether the air-breather was cold-blooded or warm-blooded.

The biconcavity of the vertebræ would sustain the first conclusion, and consequently a reference of the extinct animal, so fragmentarily indicated, to the Reptilian, not the Mammalian class.

But what further insight into the nature of such Reptile could be gained by contemplation of a solitary centrum, or even of a series of vertebræ? With me no further step could be taken toward a sure knowledge of the nature of the cold-blooded air-breather, so partially indicated. A suspicion, at most, of an aquatic medium, and consequently of limb-structures adapted to locomotion therein, might have crossed the mind. But a complete reconstruction of the extinct animal, or certain knowledge of such, could only be the result of acquisition and comparison of the anatomy of the cranium, as well as of the limbs and their sustaining arches; and such has been the knowledge supplied by the subjects of the foregoing pages of the present Monograph.

Here I may remark that instances of ancient extinct forms, manifesting a more generalised type, are more than ever worthy of note in the present phase of biological science; and the *Ichthyopterygia* contribute a welcome addition to this suggestive class of phenomena. In the construction of their chief natatory organ for forward movement may be discerned a combination of mammalian, saurian, and ichthyic conditions. In the great length and gradual diminution of the caudal series of vertebræ may be noted the saurian character; the tegumentary expansion, unsupported by bony rays, recalls the main feature of the cetaceous tail-fin, while its vertical position in the air-breathing Saurian brings it in close parallel relation with the corresponding natatory propeller in the class of Fishes.

Nevertheless, the Ichthyosaur, as an aquatic air-breather, might be supposed to have exchanged, at a loss, the disposition of its terminal fin in comparison with its aquatic warm-blooded, fish-like suecessors; but the pair of hind pelvic fins, wanting in all Cetaceans, are superadded to the locomotive instruments in the Ichthyosaurs, and were, doubtless, actively applied to bring the nostrils, when needed, within range of the superaqueous atmosphere.

But in almost every extinct natural group of animals peculiar conditions present themselves. In no known cold-blooded Fishes was the visual organ so well, or so conspicuously adapted to the detection of the finny prey as in our present subjects. To unusual size of eyeball, which in Dr. Buckland's experience sometimes reached that of a man's head, was added a circle of concomitantly large bones—the 'sclerotic plates'—of form and structure in harmony with the requirements of the visual outlooks. Was a near object to be detected, the retraction of the bony circle and contraction of its aperture, surrounded by the laterally overlapping plates, would coincide with a concomitant convexity of the cornea pressed upon by the squeezed humours within and with the contraction of the pupil—conditions concurring in the needed microscopic application of the eye.

If the distant expanse of waters was to be scanned, the resumption of the normal position of the sclerotic ring and of the relaxed relations of the overlapping plates would coincide with an expansion of the pupil and flattening of the cornea, whereby the eye would thus acquire a telescopic range. Moreover, the wide transparent corneal aperture of the conspicuously large organ of vision would enable the predatory Saurian to take advatage of the least amount of light penetrating the depths of its marine environment.

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„ „ Caudal vertebræ, Part III, pp. 54—56, Pl. XIX, figs. 3, 5.

„ „ Cervical vertebræ, Part III, p. 47, Pl. XVIII.

„ „ Dentition, Part III, p. 49, Pl. XVII; XVIII.

„ „ Femur, Part III, p. 52, Pl. XVIII.

„ „ Humerus, Part III, p. 51, Pl. XVIII.

„ „ Jaws, Part III, p. 50, Pl. XVIII.

„ „ Mandible, Part III, p. 49, Pl. XVIII.

„ „ Metacarpals, Part III, p. 51, Pl. XVIII; XIX.

„ „ Metatarsals, Part III, p. 53, Pl. XVIII.

„ „ Pelvis, Part III, pp. 46, 47, Pl. XVIII; XIX, fig. 2.

„ „ Phalanges, Part III, pp. 51, 53, Pl. XVIII; XIX.

„ „ Scapula, Part III, p. 51, Pl. XVIII.

„ „ Skull, Part III, p. 48, Pl. XVIII.

„ „ Tail, Part III, p. 54, Pl. XIX.

„ „ Tibia, Part III, p. 52, Pl. XVIII.

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„ Antibrachials, Part III, p. 105; Pl. XXVIII, fig. 1; XXIX, fig. 2; XXX, figs. 1, 3; XXXI, fig. 1; XXXII, figs. 1, 4, 6, 7; XXXIII, fig. 1.

„ Atlas, Part III, p. 88, Pl. XXIII, figs. 2—6.

„ Basioccipital, Part III, p. 93, Pl. XXV, fig. 1; XXVI, fig. 1.

„ Basisphenoid, Part III, p. 94, Pl. XXV, fig. 1.

„ Bones of the head, Part III, pp. 92—103, Pl. XXIII, fig. 1; XXIV, figs. 1, 2; XXV, fig. 1; XXVI, fig. 1; XXVII, fig. 1; XXVIII, figs. 1, 2, 3; XXIX, figs. 1, 2; XXX, figs. 1, 3; XXXI, figs. 1, 2, 5; XXXII, figs. 1, 2, 7.

„ „ Limbs, Part III, pp. 103—106, Pl. XXVIII, figs. 1, 4, 5; XXIX, fig. 2; XXX, figs. 1, 3; XXXI, figs. 1, 3; XXXII, figs. 1, 7; XXXIII, fig. 1.

„ „ Trunk, Part III, pp. 87—92; XXI, figs. 1—4; XXII; XXIII; XXVI, fig. 1; XXVII, figs. 2—5; XXVIII, fig. 4; XXIX, fig. 2; XXX, figs. 1, 2; XXXI, figs. 1, 4; XXXII, figs. 1, 7, 10; XXXIII, figs. 2—7.

„ Carpals, Part III, p. 105; Pl. XXVIII, fig. 1; XXIX, fig. 2; XXX, figs. 1, 3; XXXI, fig. 1; XXXII, figs. 1, 4, 6, 7; XXXIII, fig. 1.

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„ Coracoid, Part III, p. 104, Pl. XXVIII, fig. 4; XXX, fig. 3; XXXI, fig. 4.
„ Diapophyses, Part III, pp. 89, 90, Pl. XXI, figs. 1—4; XXII; XXIII, fig. 6; XXVII, figs. 4, 5; XXXIII, figs. 2—7.
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„ Foramen magnum, Part III, p. 102, Pl. XXVI, fig. 1.
„ Foramen parietale, Part III, p. 103, Pl. XXIII, fig. 1.
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„ Hæmal spine, Part III, p. 92, Pl. XXI, figs. 2, 4, 5.
„ Hæmapophyses, Part III, p. 88, Pl. XXI, fig. 2; Pl. XXVIII, fig. 1.
„ Humerus, Part III, p. 105, Pl. XXVIII, fig. 1; XXIX, fig. 2; XXX, figs. 1, 3 XXXI, figs. 1, 4; XXXII, figs. 1, 4, 6, 7; XXXIII, fig. 1.
„ Hyoid, Part III, p. 95, Pl. XXV, fig. 3.
„ Hypapophyses, Part III, pp. 88, 89; Pl. XXIII, fig. 5; XXVII, fig. 2.
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„ Interpterygoid, Part III, p. 102, Pl. XXV, fig. 1.
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„ Lacrymal, Part III, p. 101, Pl. XXIV, fig. 1.
„ Malar, Part III, p. 101, Pl. XXIV, fig. 1.
„ Mandible, Part III, p. 96, Pl. XXIV, fig. 2; XXVI, figs. 2—7; XXIX, fig. 1; XXX, figs. 2—4; XXXI, figs. 2, 5; XXXII, fig. 2.
„ Mastoid, Part III, p. 95, Pl. XXIII, fig. 1; XXIV, fig. 1; XXVI, fig. 1.
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„ Orbit, Part III, p. 102, Pl. XXIII, fig. 1; XXIV, figs. 1, 2; XXVII, fig. 1; XXVIII, figs. 1—3; XXIX, figs. 1, 2; XXX, fig. 1; XXXI, figs. 2, 5; XXXII, figs. 1, 2, 7.
„ Palatines, Part III, p. 99, Pl. XXV, fig. 1.
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„ Presphenoid, Part III, p. 96, Pl. XXV, fig. 1.
„ Prosquamosal, Part III, p, 101, Pl. XXIV, fig. 1.
„ Pterygoid, Part III, p. 100, Pl. XXV, fig. 1 ; XXVI, fig. 1.
„ Pterygomalar, Part III, p. 102, Pl. XXV, fig. 1.
„ Scapula, Part III, p. 104, Pl. XXVIII, fig. 4 ; XXX, fig. 3 ; XXXI, figs. 3, 4.
„ Sclerotic plates, Part III, p. 103, Pl. XXIV, figs. 1, 2 ; XXVIII, figs. 1, 2, 3 ; XXIX, fig. 1 ; XXXI, figs. 2, 5 ; XXXII, fig. 7.
„ Skull, Part III, p. 92, Pl. XXIII, fig. 1 ; XXIV, figs. 1, 2 ; XXV, fig. 1 ; XXVI, figs. 1—7, XXVII, fig. 1 ; XXVIII, figs. 1, 2, 3 ; XXIX, figs. 1, 2 ; XXX, figs. 1, 3 ; XXXI, figs. 1, 2, 5 ; XXXII, figs. 1, 2, 7, 8.
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„ Zygapophyses, Part III, p. 88, Pl. XXI, fig. 6.

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„ Species of, Part III, pp. 109—127, Pls. XXII—XXXIII.

„ acutirostris, *Owen*, Part, III, p. 121, Pl. XXVIII, fig. 2.
„ breviceps, *Owen*, Part III, p. 109, Pl. XXIX.
„ brachyspondylus, *Owen*, Part III, p. 127, Pl. XXXIII, figs. 3—6.
„ communis, *Conybeare*, Part III, p. 111, Pl. XXIV, figs. 2, 5, 5′ ; XXVIII, fig. 1 ; XXX, figs. 3, 4, 5.
„ intermedius, *Conybeare*, Part III, p. 113, Pl. XXIV, fig. 7 ; XXX, figs. 1, 2.
„ latifrons, *König*, Part III, p. 119, Pl. XXIII, fig. 6 ; XXVII, fig. 1.
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„ longirostris, *Owen*, Part III, p. 124, Pl. XXV, fig. 2 ; XXVIII, fig. 3 ; XXXII, figs. 7, 8, 9.
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„ „ Caudal vertebræ, Part III, p. 7, Pl. I, fig. 1 ; IV, figs. 3—9.
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„ „ Pectoral and pelvic arches and limbs, Part III, p. 18, Pl. V; VIII.
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„ rostratus, *Owen*, Part III, pp. 20—33, Pls. IX—XIII.
„ „ Pectoral and pelvic arches and limbs, Part III, p. 30, Pl. IX, fig. 1.
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„ „ Centrum of Dorsal vertebra, Part I, p. 5, Pl. 3, figs. 1—4.
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„ „ Dermo-skeleton, Part II, 20—25, Pl. I, fig. 1; II; III; VI, fig. 1; VII, fig. 4; VIII, figs. 1, 3; IX, figs. 1, 2, 5.
„ „ Femur, Part I, p. 2, Pl. I; III, figs. 5, 6.
„ „ Fibula, Part I, p. 5, Pl. III, figs. 8, 9.
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„ „ Scapular arch and limb, Part II, p. 12, Pl. II; III.
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„ „ Ungual phalanx, Part I, p. 5, Pl. II, figs. 4, 5, 6.
„ „ Vertebral column, Part II, p. 2, Pls. I—IX.

PLATE XXI.

Ichthyosaurus.

Typical vertebræ.

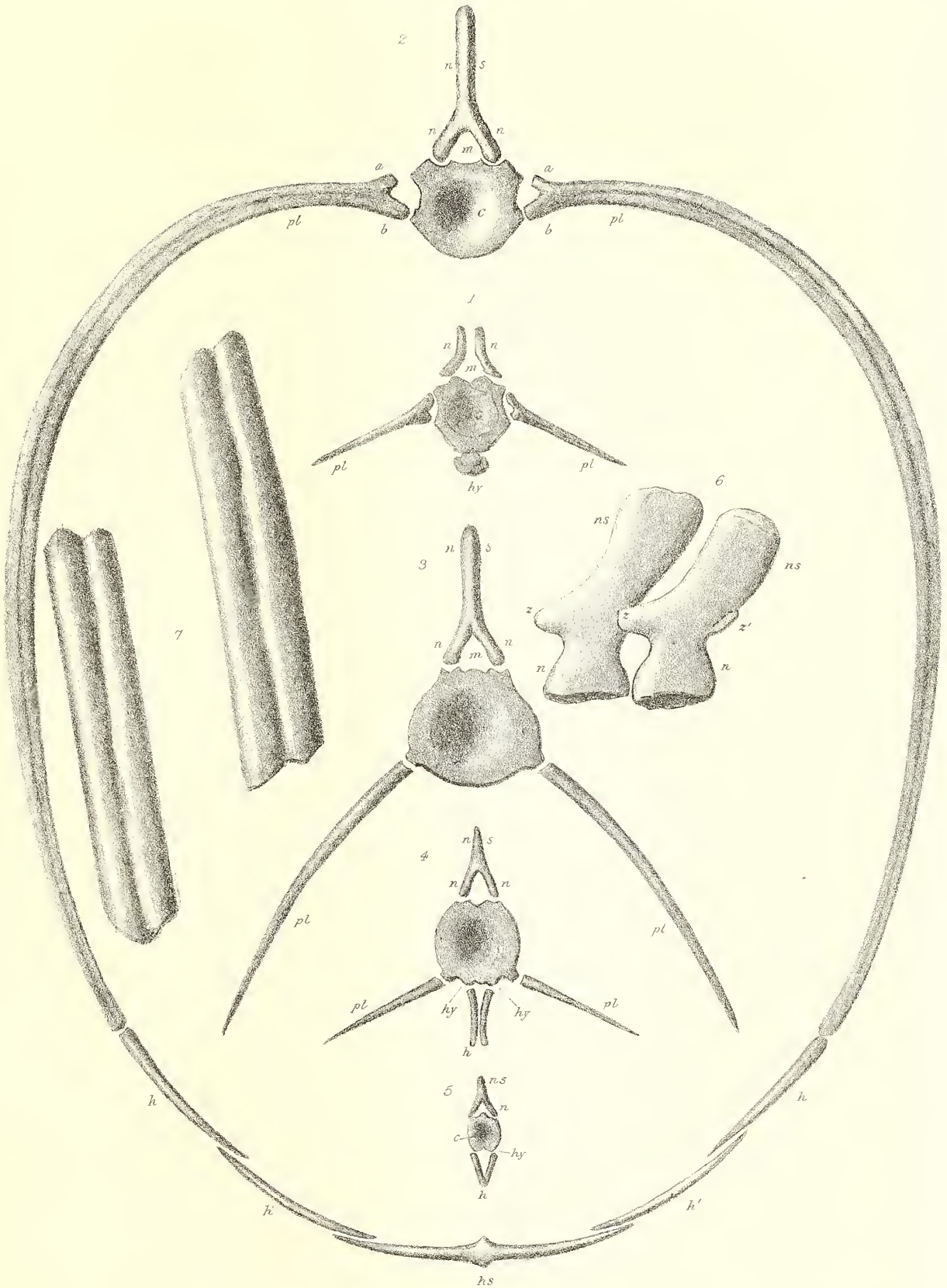
Fig.

1. First or atlas vertebra.
2. Trunk-vertebra.
3. Pelvic vertebra.
4. Caudal vertebra.
5. Terminal or pinnigerous vertebra.

(These figures are less than the natural size.)

6. Neural arches of trunk-vertebræ, side view.
7. Portions of pleurapophyses of trunk-vertebræ, outer side view.

(These figures are of a small specimen, natural size.)



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ICHTHYOSAURUS.
TYPICAL VERTEBRÆ

PLATE XXII.

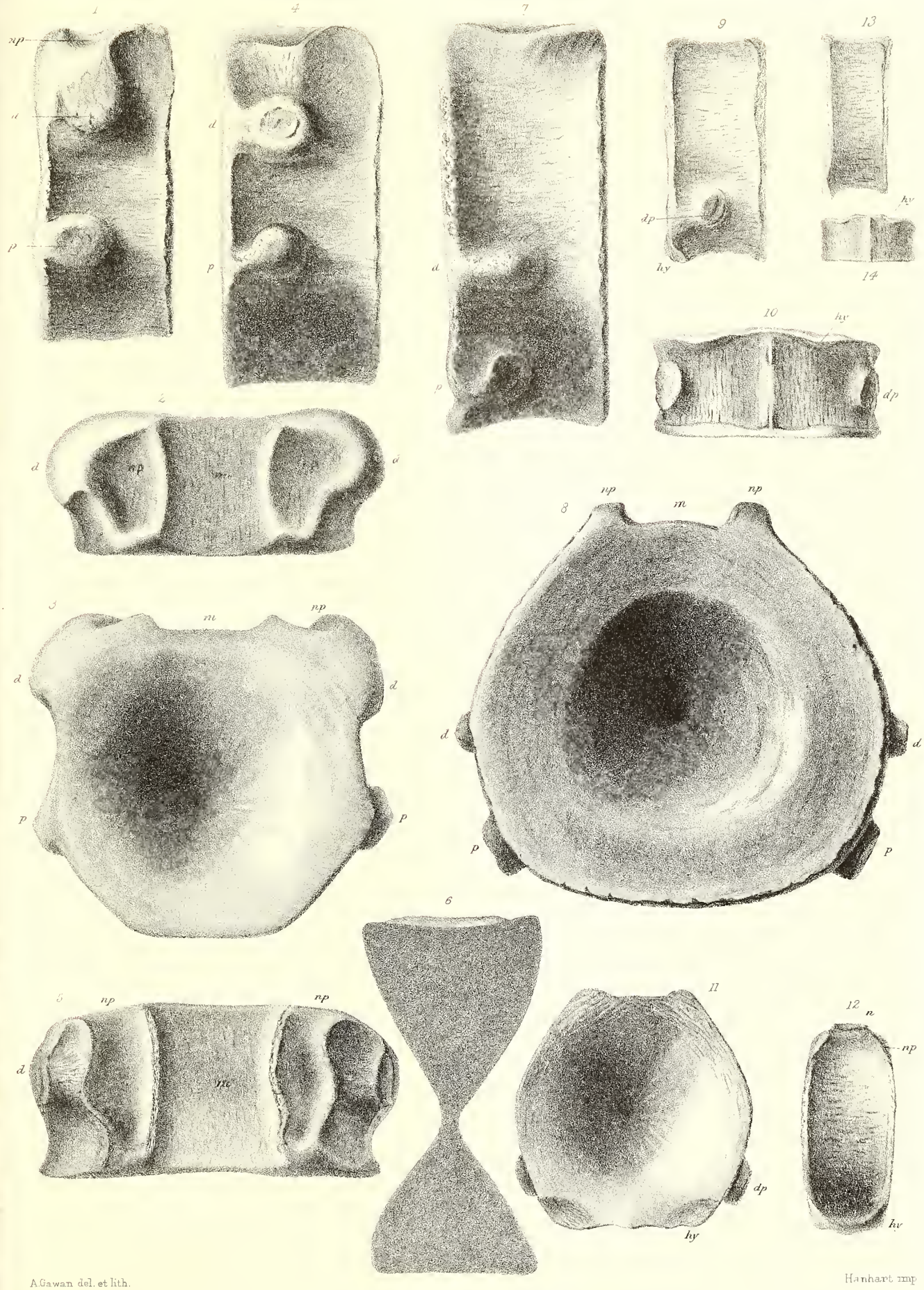
Ichthyosaurus.

Vertebral centrums; regional characters.

Fig.

1. Anterior trunk-vertebra, side view.
2. Ib. upper view.
3. Ib. front view.
4. Middle trunk-vertebra, side view.
5. Ib. upper view.
6. Ib. vertical transverse section.
7. Posterior trunk-vertebra, side view (*Ich. latimanus*).
8. Ib. front view (ib.).
9. Caudal vertebra, side view.
10. Ib. under view.
11. Ib. front view.
12. Posterior caudal vertebra, side view.
13. Ib. from base of pinnigerous portion, side view (*Ich. latimanus*).
14. Ib. under view.

(All the figures are of the natural size.)



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ICHTHYOSAURUS.

REGIONAL CHARACTERS OF VERTEBRÆ.

PLATE XXIII.

Ichthyosaurus.

Cranial and vertebral characters.

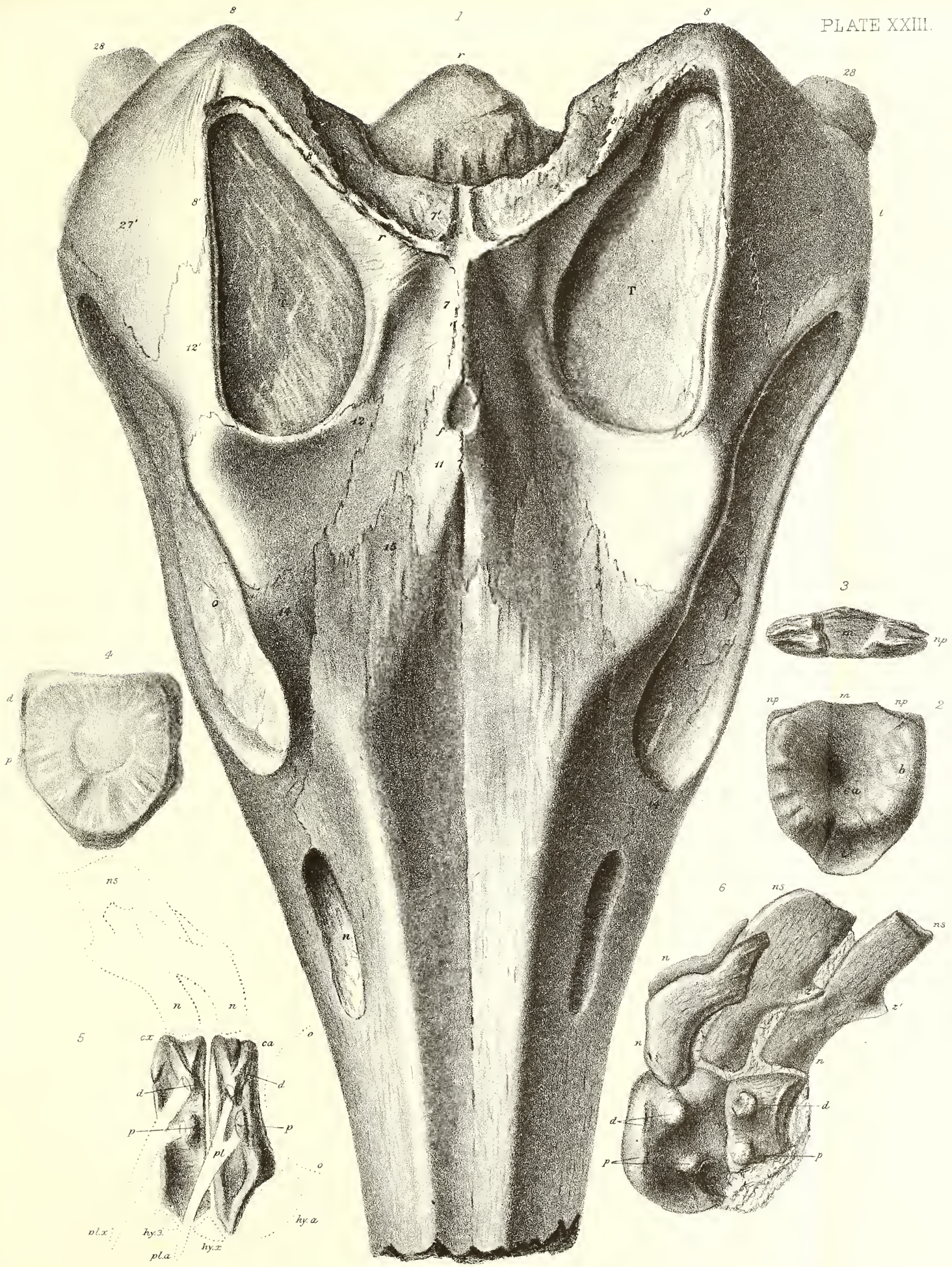
Fig.

1. Skull, lacking end of snout, upper view (*Ich. longifrons*, Ow.).
2. Centrum of atlas vertebra, front view (ib.).
3. Ib. upper view (ib.).
4. Ib. back view (ib.).
5. Atlas and axis vertebræ, side view (ib.).
6. Atlas, axis, and third vertebræ, side view (*Ich latifrons*).

Figs. 1—5 are from the Upper Lias.

Fig. 6 is from the Lower Lias.

(All the figures are of the natural size.)



A. Gawan del et lith

ICHTHYOSAURUS LONGIFRONS.

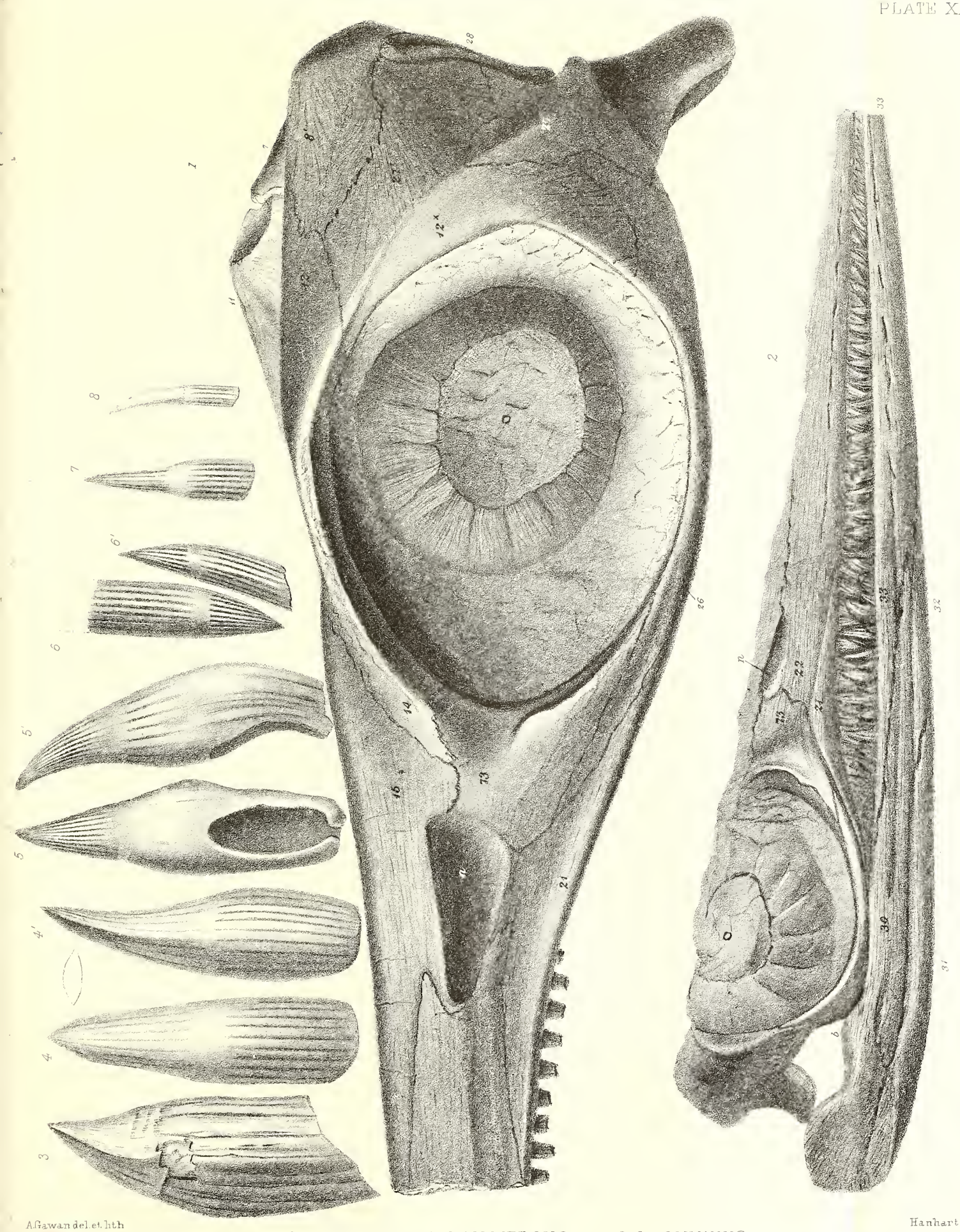
Hanhart imp

PLATE XXIV.

Ichthyosaurus.

Fig.

1. Skull (lacking end of snout), side view (*Ich. longifrons*).
2. Skull (lacking upper surface), side view (*Ich. communis*).
3. Tooth of *Ich. trigonodon*.
4, 4′. Teeth of *Ich. platyodon*.
5, 5′. Teeth of *Ich. communis*.
6, 6′. Teeth of *Ich. lonchiodon*.
7. Tooth of *Ich. intermedius*.
8. Tooth of *Ich. tenuirostris*.



A.Gawan del.et.lith

1. ICHTHYOSAURUS LONGIFRONS, 2. I. COMMUNIS

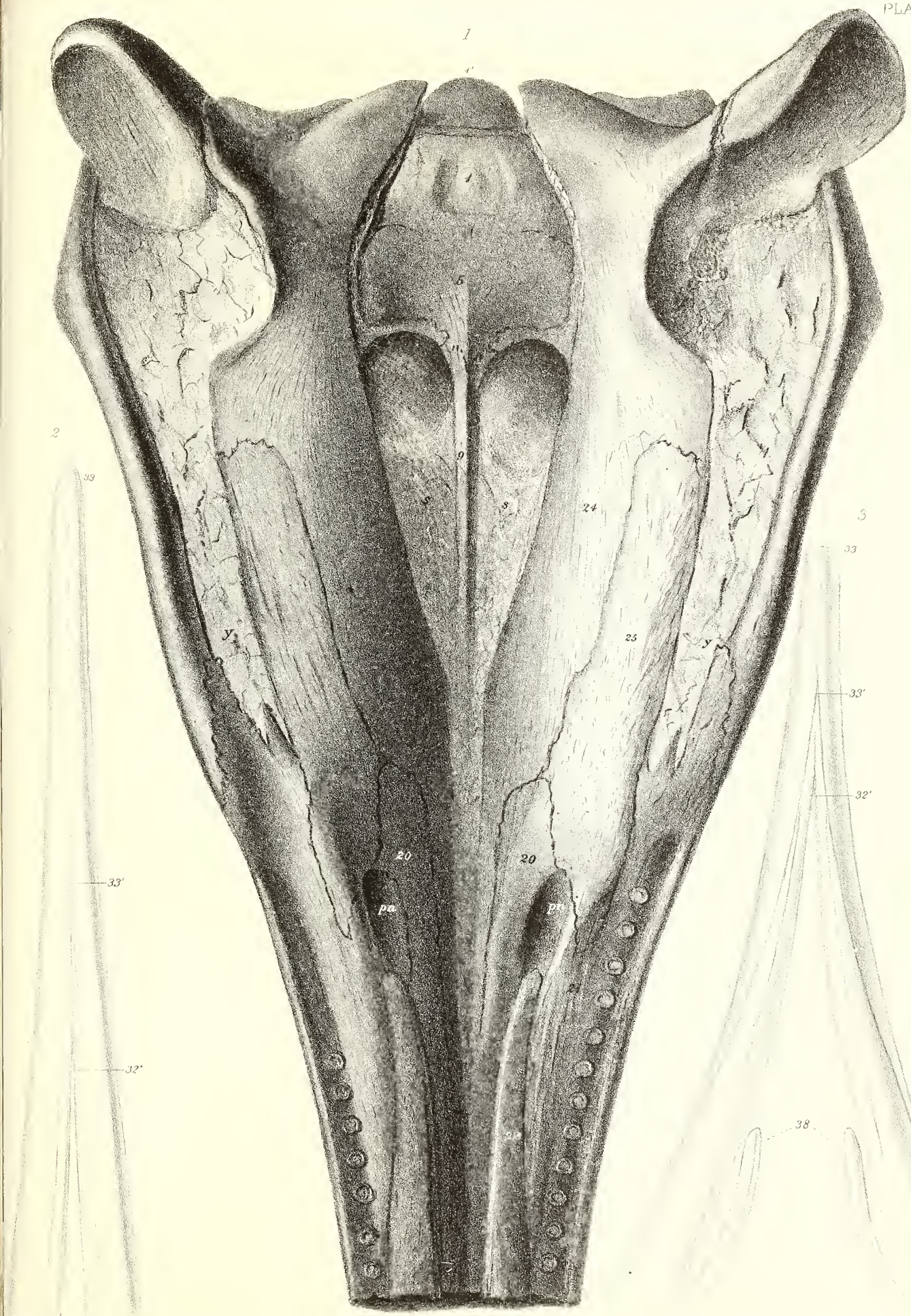
Hanhart imp.

PLATE XXV.

Ichthyosaurus.

Fig.

1. Skull (lacking lower jaw and end of upper jaw), base view (*Ich. longifrons*).
2. Outline of lower view of symphysial end of mandible (*Ich. longirostris*).
3. Ib. with hyoid bones (*Ich. tenuirostris*).



1. ICHTHYOSAURUS LONGIFRONS 2. ICH. LONGIROSTRIS; 3. ICH. TENUIROSTRIS

Let. lith.

Hanhart imp

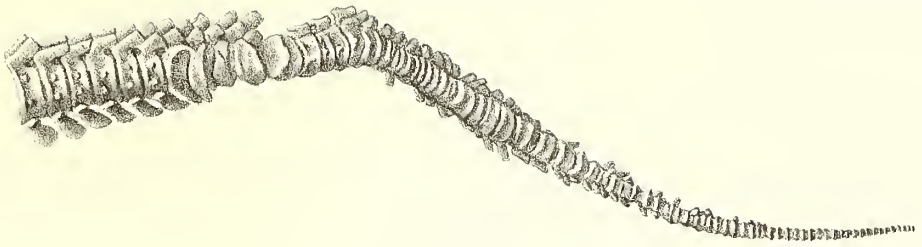
PLATE XXVI.

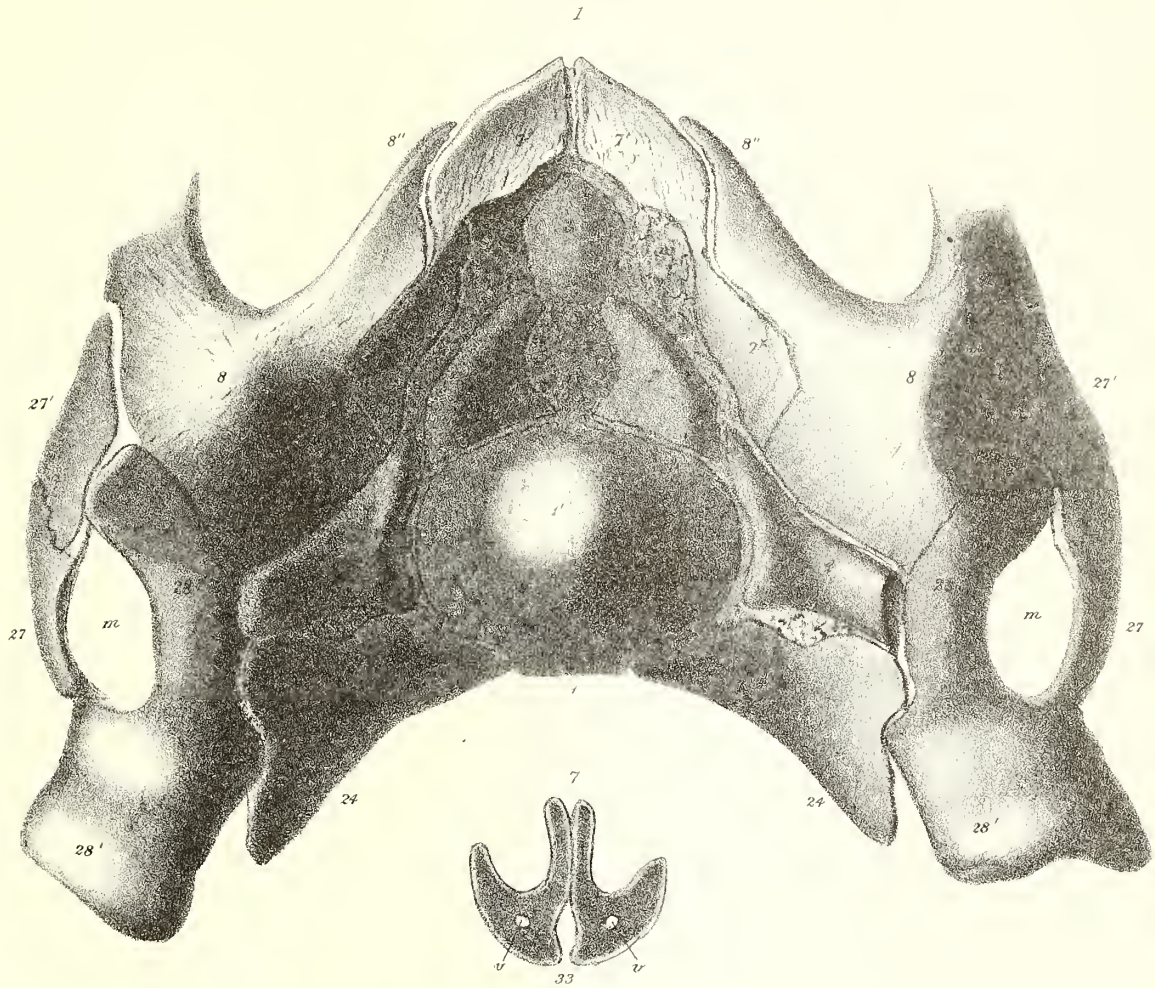
Ichthyosaurus.

Fig.

1. Skull (lacking the lower jaw), back view (*Ich. longifrons*).
2. Vertical transverse section of hind end of mandibular ramus (*Ich. intermedius*).
3. Ib., somewhat in advance of fig. 2 (ib.).
4. Ib., across the hinder end of the dentary element (ib.).
5. Ib., in advance of the mid-length of mandibular ramus (ib.).
6. Ib., across the anterior end of the surangular and splenial elements (ib.).
7. Ib., near the anterior end of both mandibular rami (ib.).
8. Terminal caudal vertebræ with accidentally deflected pinnigerous end (ib.).

(All the figures save the last are of the natural size.)





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1. ICHTHYOSAURUS LONGIFRONS.

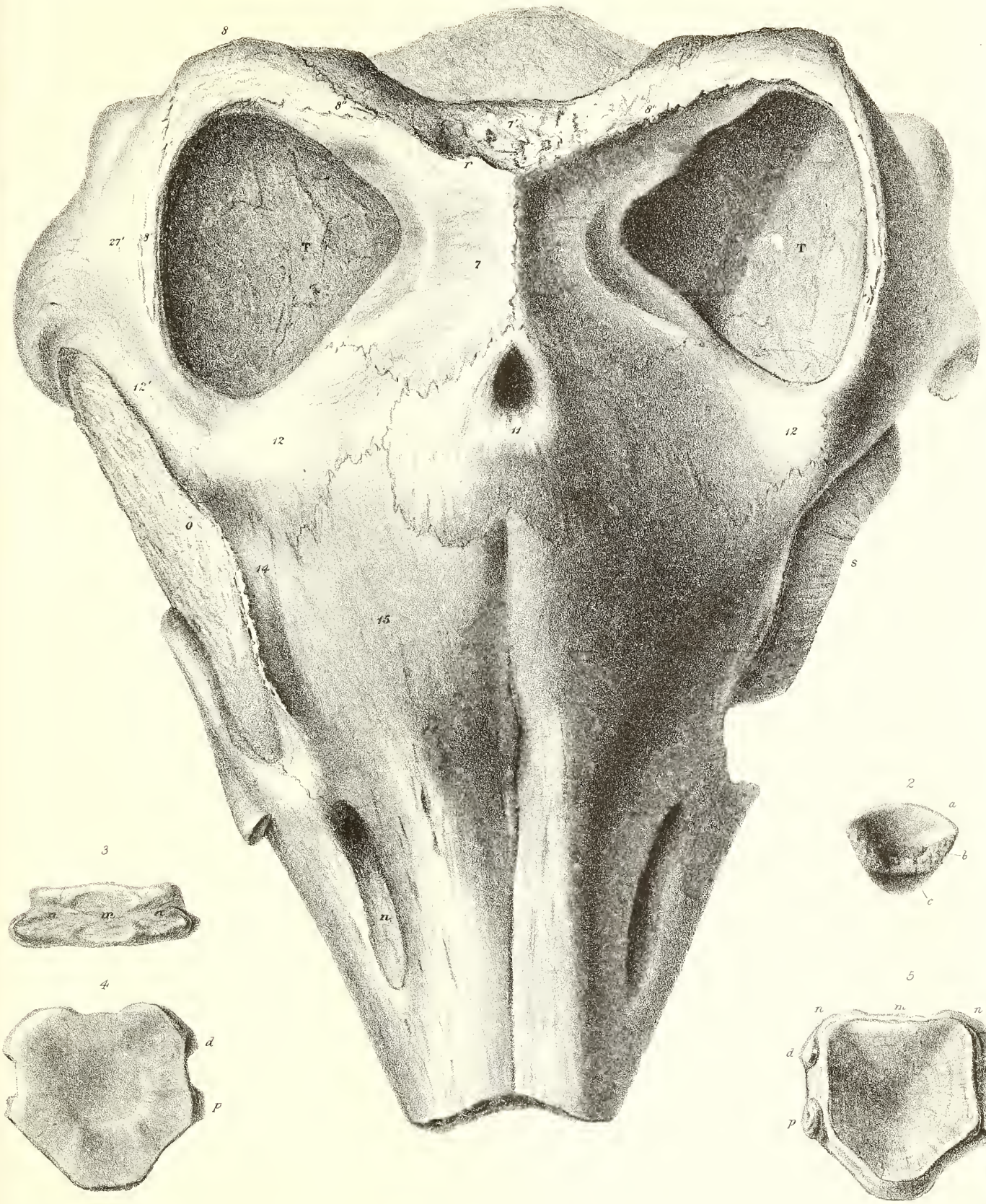
PLATE XXVII.

Ichthyosaurus.

Fig.

1. Skull (lacking end of snout), upper view (*Ich. latifrons*).
2. Hypapophysis or 'wedge-bone' of the atlas vertebra, upper view (*Ich. longifrons*).
3. Axis vertebra, upper view (ib.).
4. Ib., front view (ib.).
5. Ib., back view (ib.).

(All the figures are of the natural size.)



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Hanhart imp

1. ICHTHYOSAURUS LATIFRONS.

PLATE XXVIII.

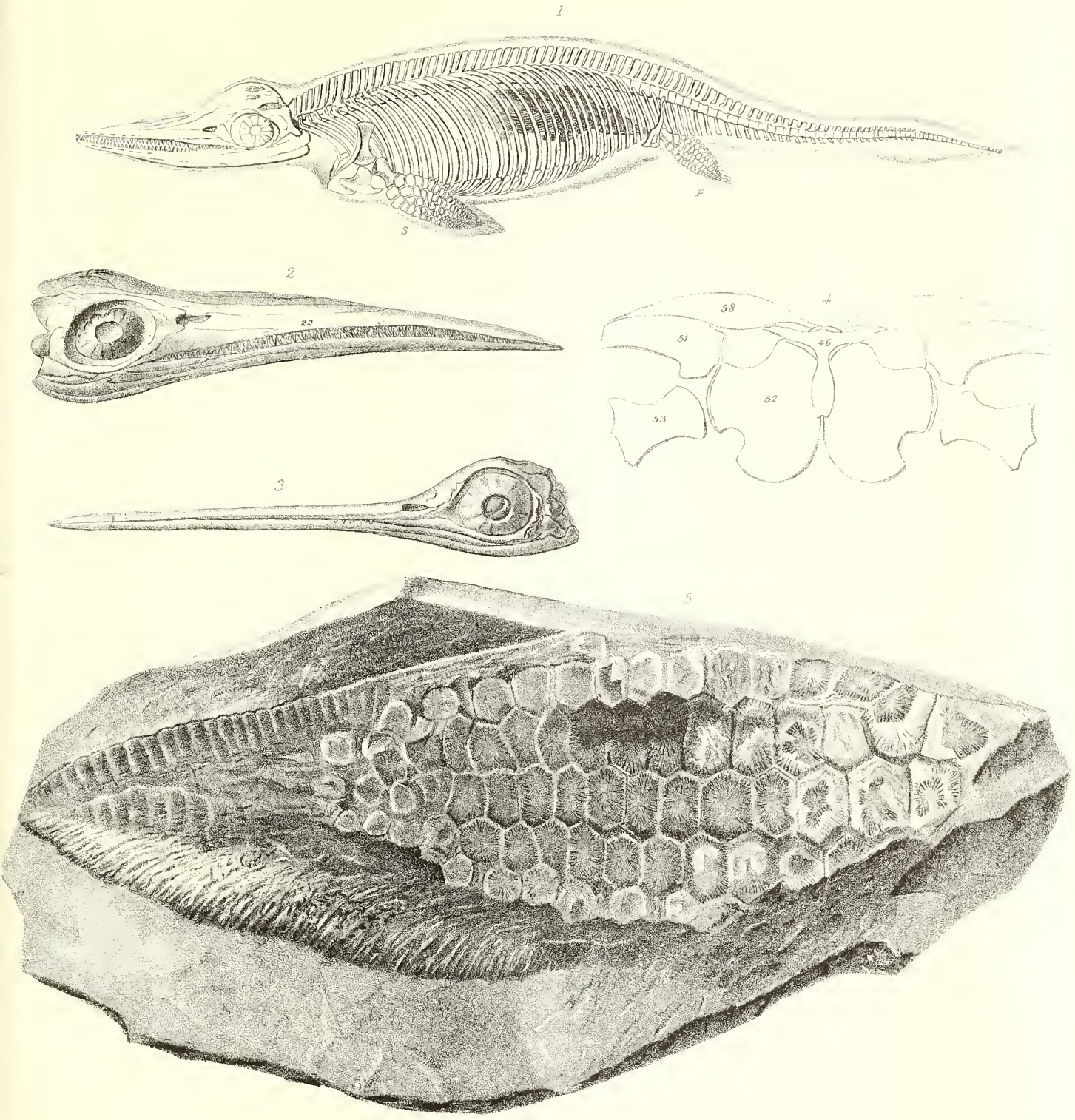
Ichthyosaurus.

Fig.

1. Restoration with skeleton and included fœtus (*Ich. communis*)
2. Skull, side view (*Ich. acutirostris*).
3. Ib., ib. (*Ich. longirostris*).
4. Scapular arches and humeri (*Ich. communis*).

(These figures are more or less reduced.)

5. Slab of Lias, with bones and part of tegumentary sheath of hind fin, nat. size (*Ich. communis ?*).



A.Gawan del. et lith

Slawan. imp

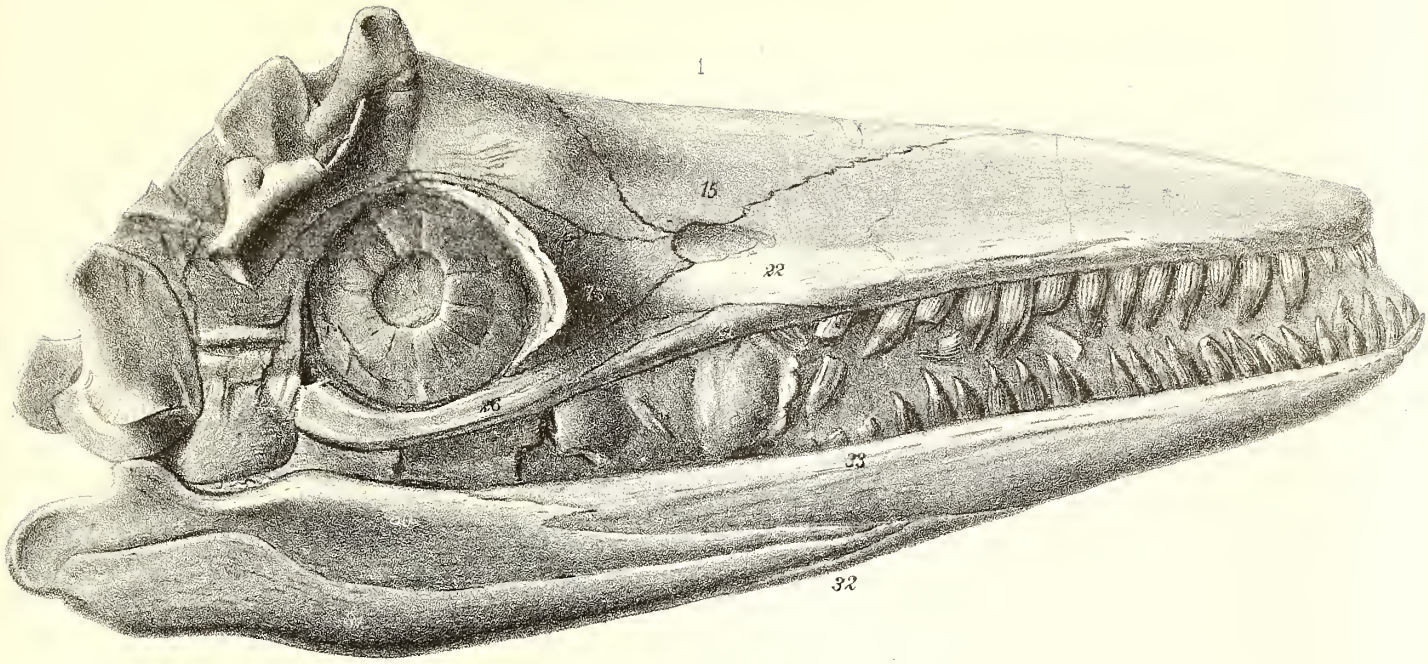
1. ICHTHYOSAURUS COMMUNIS; 2. ICH. ACUTIROSTRIS; 3. ICH. LONGIROSTRIS

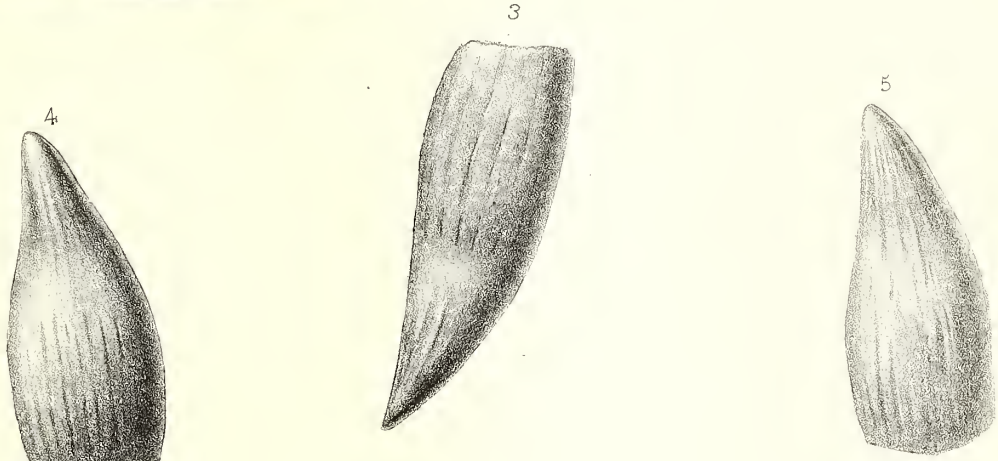
PLATE XXIX.

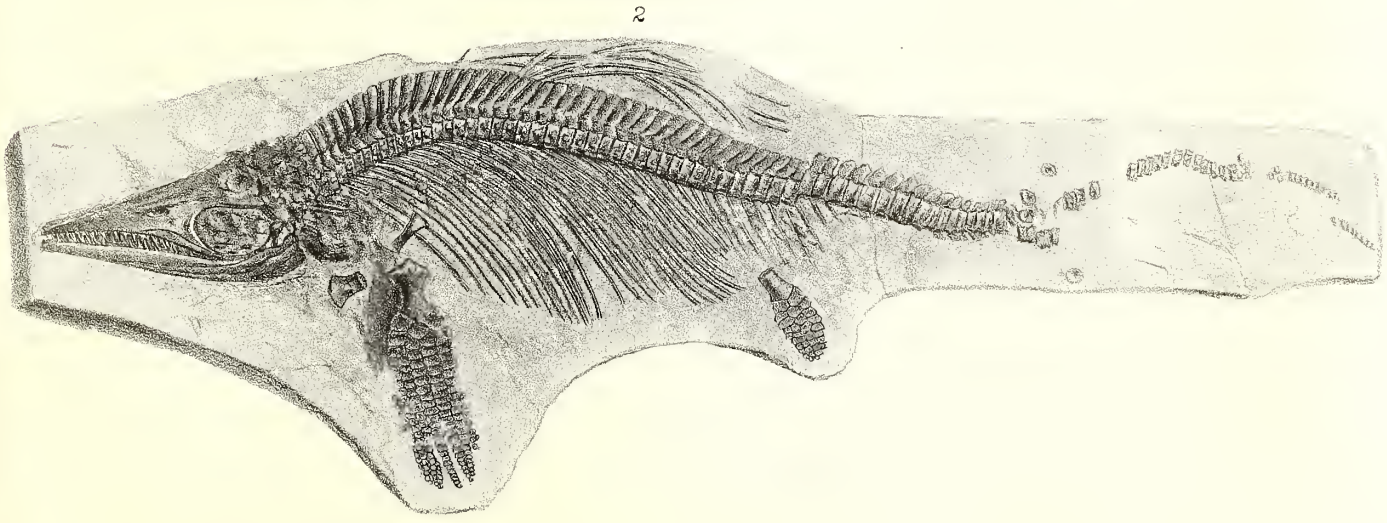
ICHTHYOSAURUS BREVICEPS, *Ow.*

FIG.

1. Skull, side view, $\frac{1}{4}$ nat. size.
2. Skeleton of a younger specimen, $\frac{1}{6}$ nat. size.
3. Tooth from upper jaw of fig. 1, nat. size.
4. Ib. from lower jaw of fig. 1, nat. size.
5. Ib. from hinder part of the series, nat. size.







Stone by J Erxleben.

Hanhart imp

ICHTHYOSAURUS BREVICEPS.

PLATE XXX.

Ichthyosaurus intermedius.

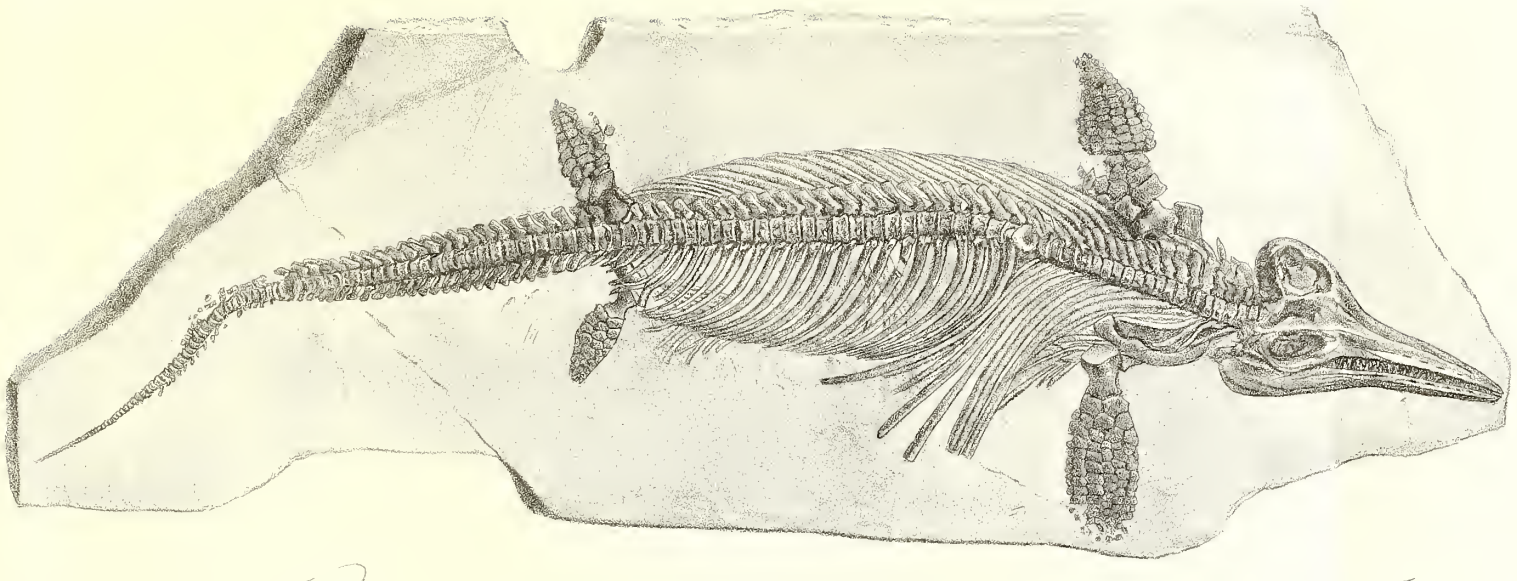
Fig.

1. Skeleton, from the dorsal aspect, $\frac{1}{8}$ nat size.
2. Symphysis mandibulæ, under view, $\frac{1}{2}$ nat. size.

Ichthyosaurus communis.

3. Portion of skeleton, from the ventral aspect, $\frac{1}{7}$ nat. size.
4. Symphysis mandibulæ, under view, $\frac{1}{2}$ nat. size.
5. Bones of pelvic arch, left side, $\frac{1}{2}$ nat. size.

1



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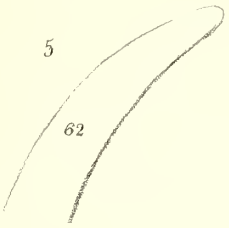

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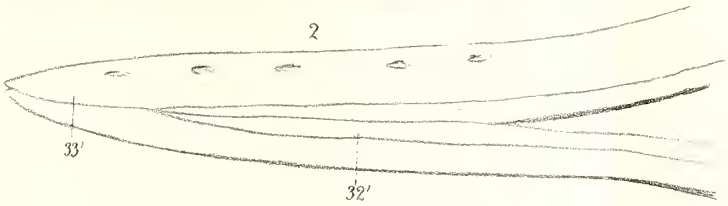

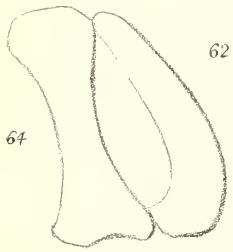

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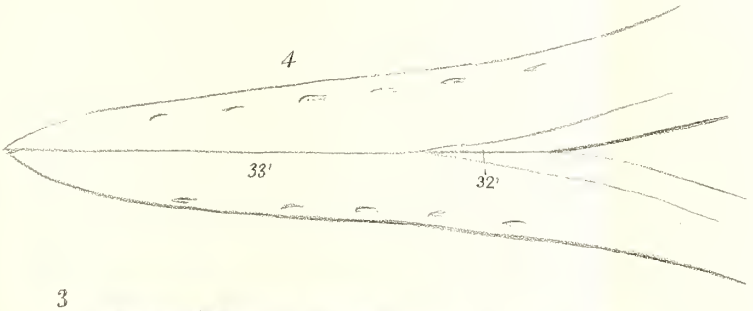

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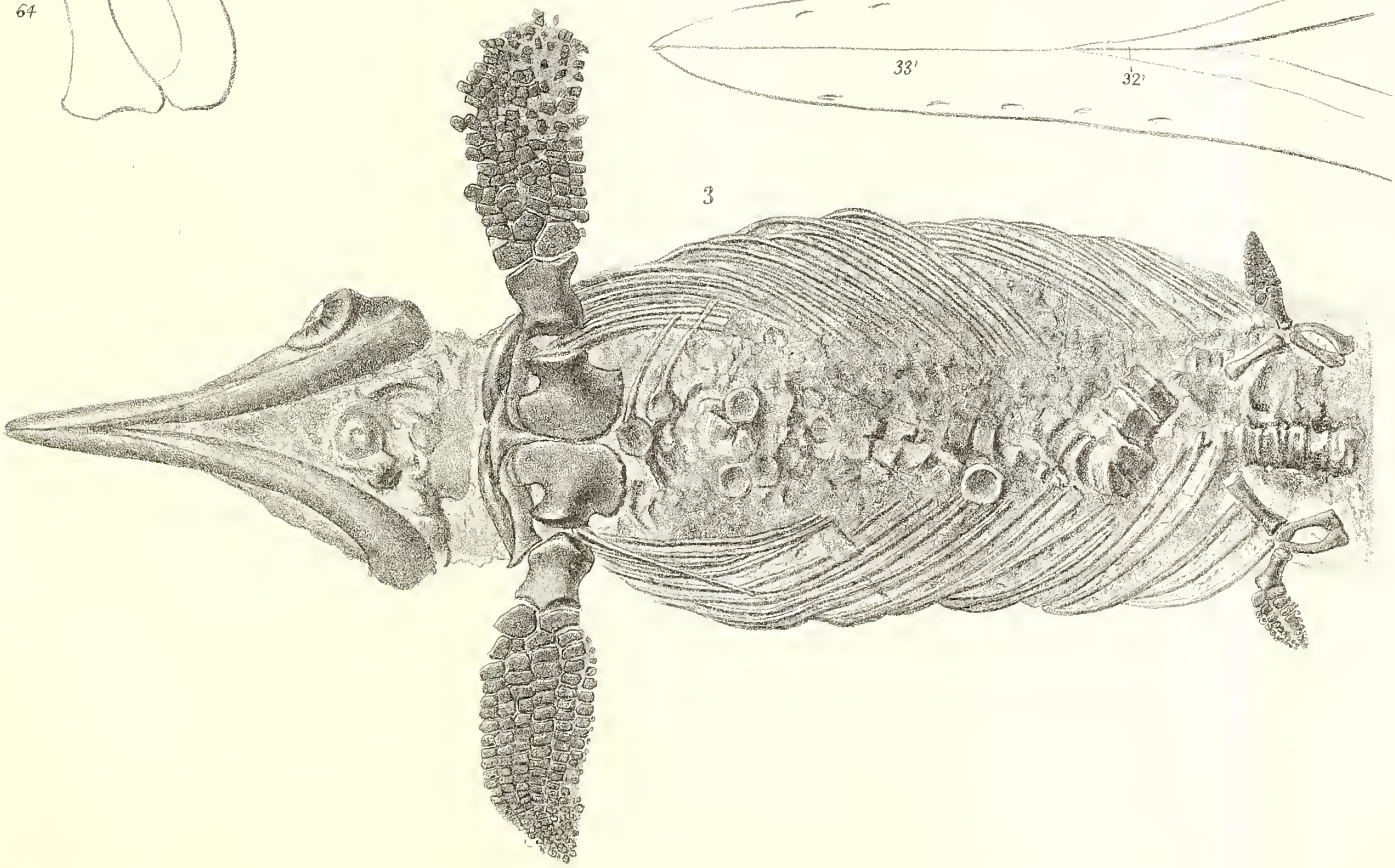

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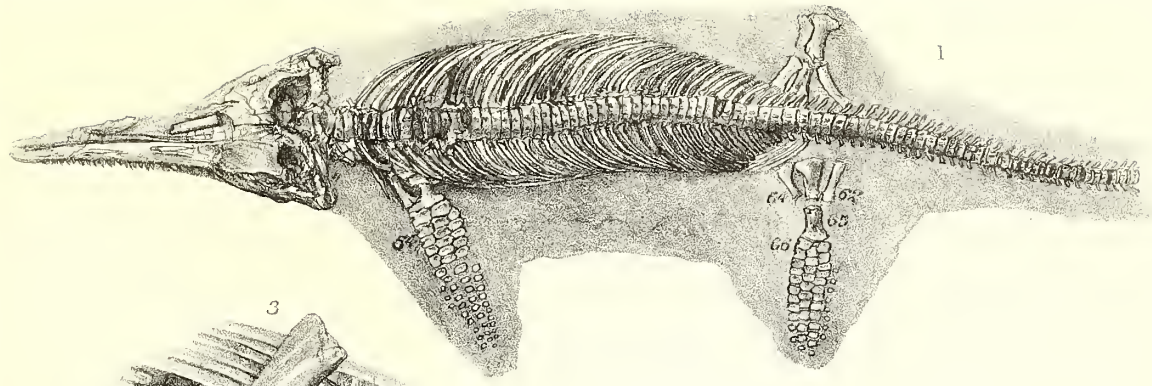
I & 2. ICHTHYOSAURUS INTERMEDIUS 3.4.5. ICH. COMMUNIS

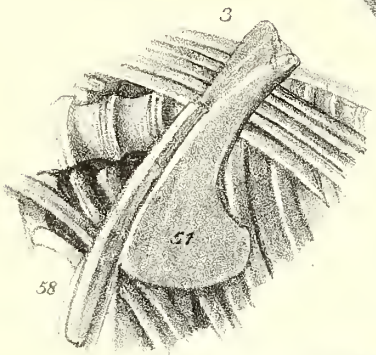
PLATE XXXI.

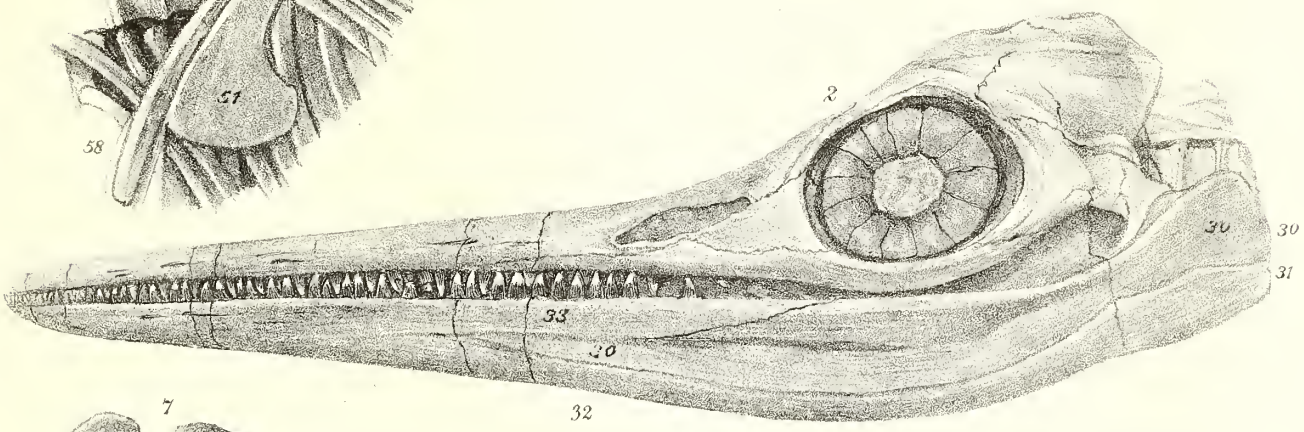
Ichthyosaurus.

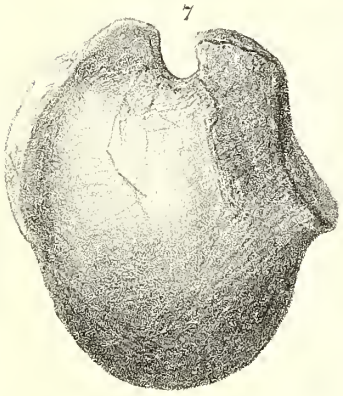
Fig.

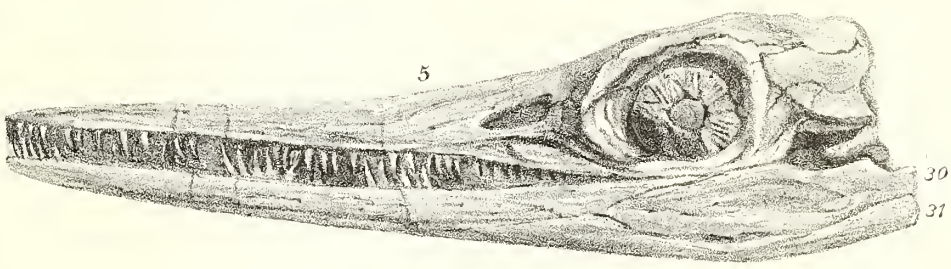
1. *Ichthyosaurus platyodon*, skeleton, dorsal aspect, much reduced.
2. Skull of do., side view, $\frac{1}{10}$ nat. size.
3. Parts of thorax and scapular arch of do., $\frac{1}{12}$ nat. size.
4. Skeleton, *minus* skull, of *Ichthyosaurus lonchiodon*, much reduced.
5. Skull of do., side view, $\frac{1}{10}$ nat. size.
6. Four trunk-vertebræ of do., side view, $\frac{1}{10}$ nat. size.
7. Right coracoid of do, outer view, $\frac{1}{5}$ nat. size.

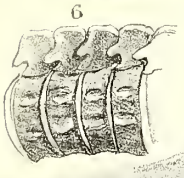


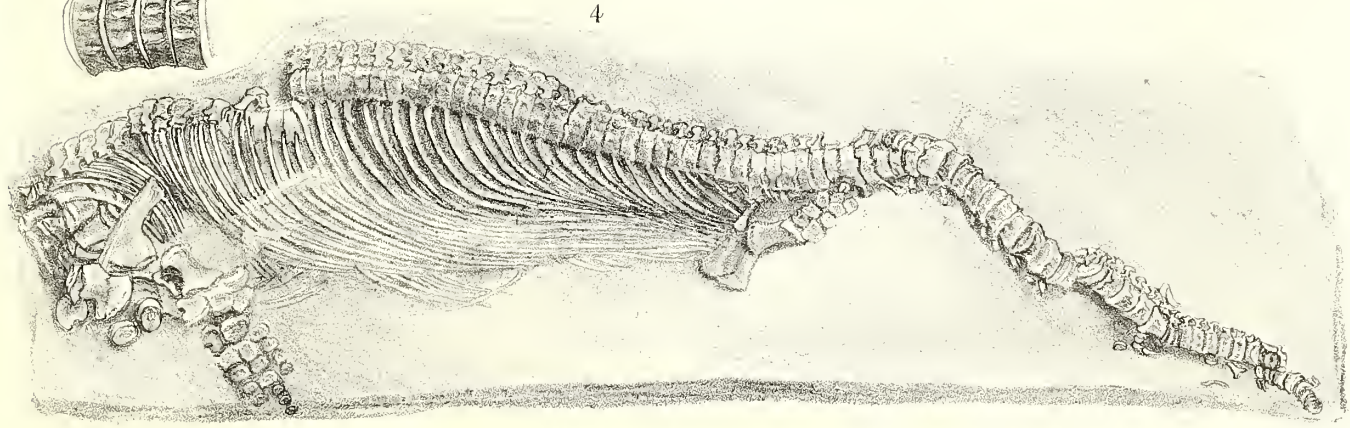












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1–3. ICHTHYOSAURUS PLATYODON; 4–7 ICH. LONCHIODON.

PLATE XXXII.

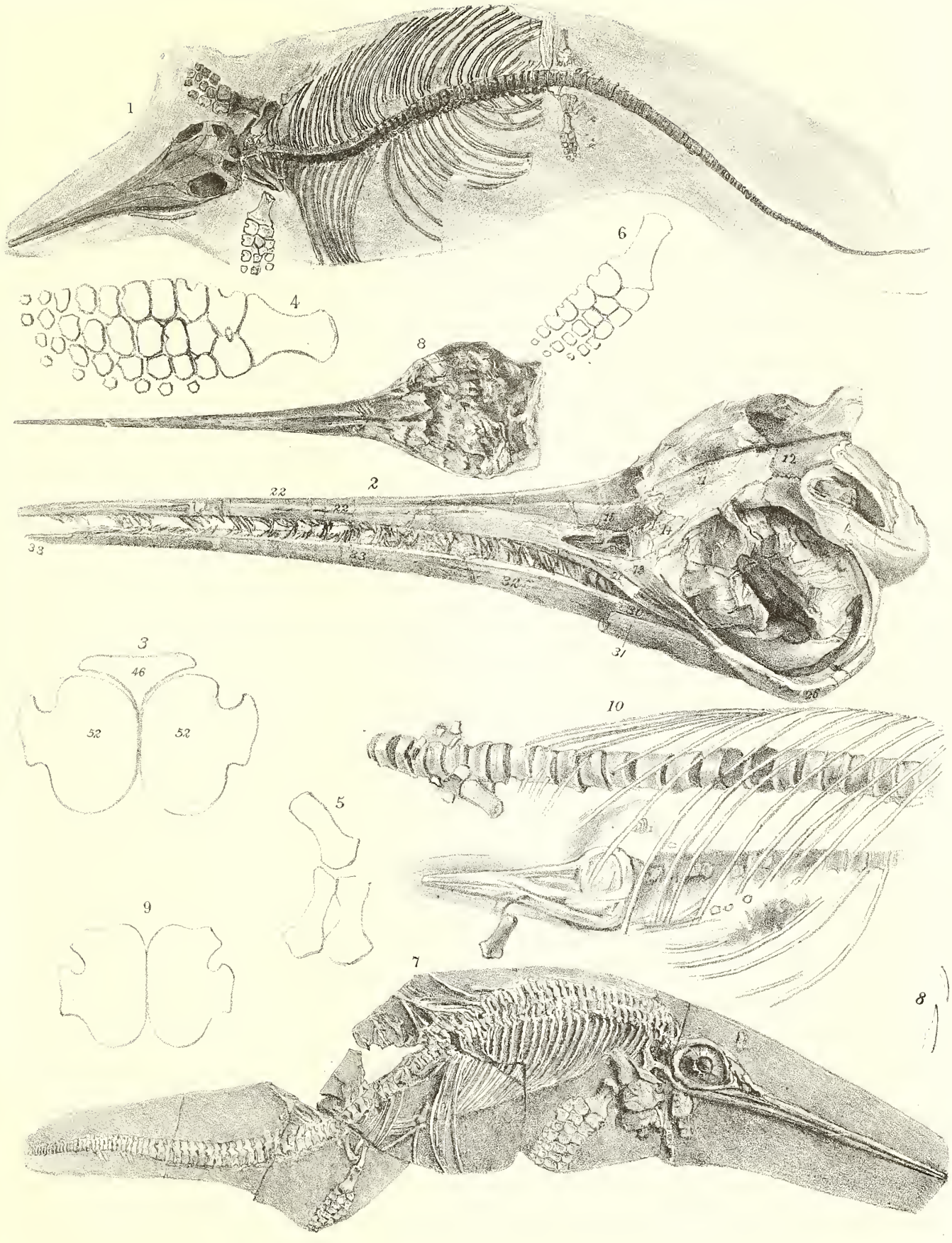
Ichthyosaurus.

Fig.

1. *Ichthyosaurus tenuirostris*, skeleton, dorsal aspect, much reduced.
2. Ib., oblique side view of skull, $\frac{1}{5}$ nat. size.
3. Ib., episternum and coracoids, ib.
4. Bones of pectoral paddle, in outline, 1-6th nat. size.
5. Pelvic bones in outline, ib.
6. Bones of pelvic paddle, in outline, ib.
7. *Ichthyosaurus longirostris*, skeleton, side view, much reduced.
8. Ib., skull, upper view, much reduced.

8′. Ib., teeth, in outline.

9. Coracoids of do., in outline, $\frac{1}{6}$ nat. size.
10. Pelvic part of skeleton, with fœtus, *Ich. intermedius* (after Jaeger).



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1_6 ICHTHYOSAURUS TENUIROSTRIS 7_9 ICH. LONGIROSTRIS 10 ICH. INTERMEDIUS.

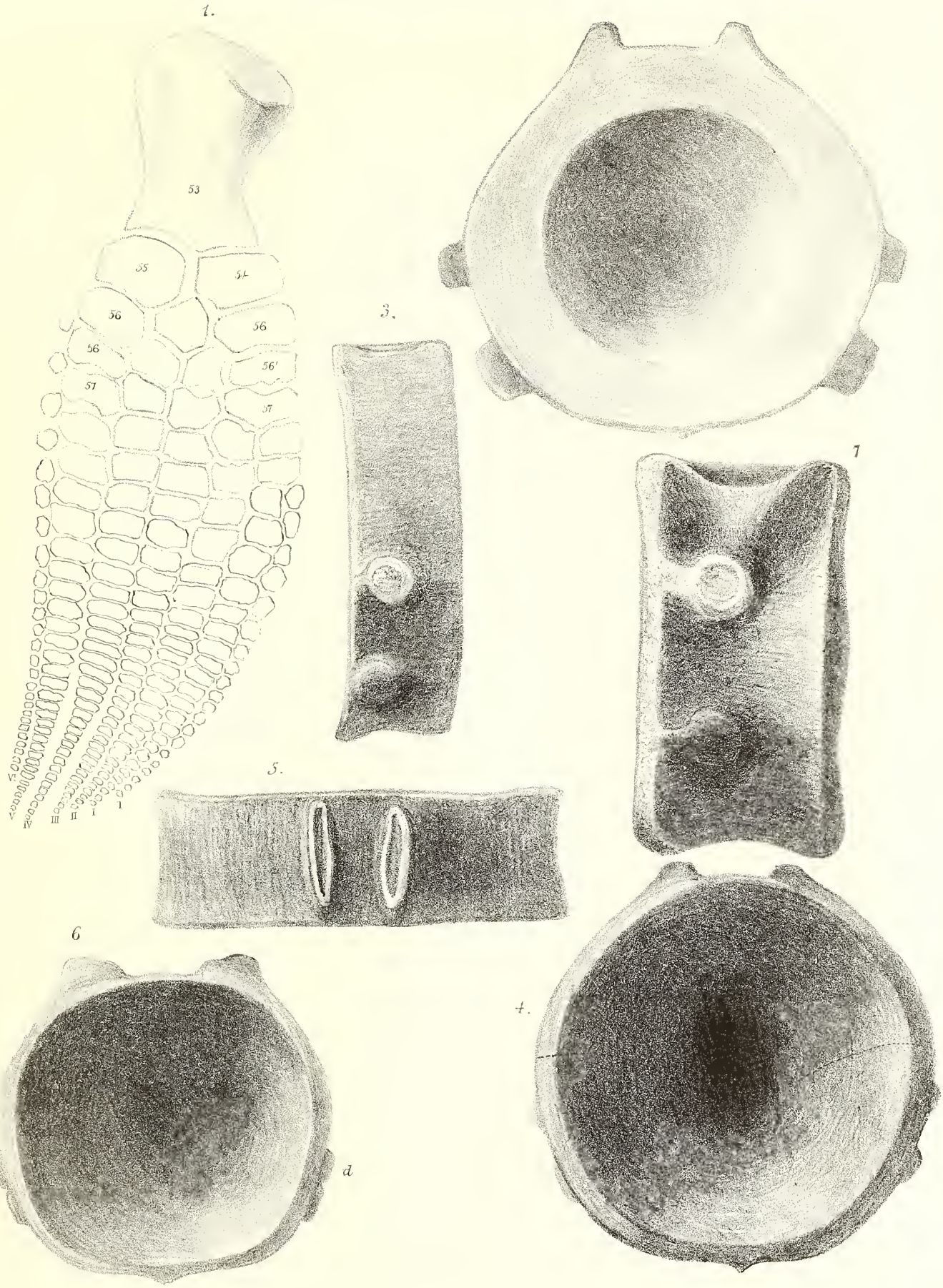
PLATE XXXIII.

Ichthyosaurus.

Fig.

1. Restoration of bones of pectoral paddle, in outline, $\frac{1}{3}$ nat. size.
2. Articular surface of centrum of *Ichthyosaurus latimanus*.
3. Side view of centrum of *Ichthyosaurus brachyspondylus*.
4. Articular surface of do., do.
5. Neural surface of do., do.
6. Articular surface of post-abdominal vertebra of do.
7. Side view of centrum of *Ichthyosaurus latimanus*.

Figs. 2—7 are of the natural size.



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I RESTORATION OF PADDLE
2,7 ICHTHYOSAURUS LATIMANUS 3,6, ICHTHYOSARUS BRACHYSPONDYLUS

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